Race and energy poverty: Evidence from African-American households

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Abstract

Even though energy poverty has been widely discussed in many countries, only a few studies attempt to understand the nexus of race and energy poverty. To fill the gap in the literature, this study analyses the effect of race on energy poverty by employing the U.S. representative household panel data with 9,043 complete surveys. This research addresses possible endogeneity issues by employing the novel method proposed by Oster (2019) as a robustness check in addition to the application of logistic regressions and ordinary least squares estimates. The empirical results show that the probability of exposure to poverty is higher for African-American households. The empirical outcome also presents that health and income are significant factors through which race influences energy poverty. This study suggests that subsidy programs would be beneficial in ensuring the breakage of the link between race and energy poverty by providing preferential discounted rates and easier access to energy to specific demographics of the population. At least ending with the housing segregation of African-Americans in the USA would be a way to surpass these difficulties and decrease energy poverty. Further discussions are presented in this study.

Keywords: energy poverty; Race; African-Americans; endogeneity

1. Introduction

Achieving a concrete definition of energy poverty is not an easy task (Faiella and Lavecchia, 2021). There is no consensus in the literature on the best way of measuring it (Siksnelyte-Butkiene et al., 2021). Energy poverty (E.P.) has been analysed in the literature from two different perspectives: the absence of physical opportunity to access adequate energy services and the impossibility of consuming and using modern energy resources for multiple reasons (Churchill and Smyth, 2020; Dogan et al., 2021). E.P. is defined as the limitations in access to energy suppliers, especially in developing countries or underdeveloped regions in developed countries, involving economic, infrastructure, social equity, education, and health (Dogan et al., 2021). It concerns both developing and developed countries, being necessary to eradicate it to achieve an appropriate level of social welfare (Halkos and Gkampoura, 2021). The E.P. concept is also valid for developed countries because sometimes E.P. is also explained as fuel poverty or energy vulnerability when household experiences barely sufficient levels of energy services (Thomson et al., 2017). E.P. calculations can focus on objective measures such as the amount of income allocated for heating purposes, or the measures can be built on subjective measures through interviews based on asking the ability of the households to maintain their house warm, pay their energy bills timely or has any issues with dwellings in their houses (Zhao et al., 2022; Thomson and Smell, 2013)

The recent literature highlights the importance of E.P. and recognises it as a complex and multi-faceted problem, affected by a range of drivers and resulting in multiple forms of vulnerability (Siksnelyte-Butkiene et al., 2021; Faiella and Lavecchia, 2021; Dogan et al., 2021; Churchill and Smyth, 2021). The literature used varying measures of E.P. and reported that some portion of the population is subject to energy poverty, especially in developing countries Zhang et al. (2021) in China, Ntaintasis et al. (2019) in Greece; Abbas et al. (2020) in six South Asian countries; as well as reported energy poverty in developed countries such as Betto et al. (2020) in Italy, Karpinska and Śmiech (2020) in Poland, Castaño-Rosa (2019) in European Union. Using cross-sectional data for USA households in 2019, this paper focuses on a less explored of these drivers in this multidimensional energy poverty context: the households' ethnic diversity or race (Churchill and Smyth, 2020; Wang et al., 2021; Paudel, 2021). More specifically, this paper concentrates on African-American households due to their community dimension in the USA.

Ethnic diversity within a country or region is mainly derived from the migration waves after post-World War II (Churchill and Smyth, 2020). It continues to be a reality nowadays due to internal conflicts, lack of job opportunities, and extreme poverty, leading persons to find better and new life opportunities (Belabas et al., 2020; Buch et al., 2021). Race is an important driver of energy poverty considering that previous studies report that Black households spend on average 12% of their income on electricity and gas when compared to non-Black households (5%), leading to a higher energy burden of 1% even when controlling for dwelling and household characteristics (Downer et al., 2021; Lyubich, 2020; Drehobl and Ross, 2016). Downer et al. (2021) studied these dynamics for the Wisconsin state, where the authors declared, "*Energy burden and energy poverty are both correlated with community-level factors including geography, housing characteristics, family size, and race*." (Downer et al., 2021, p.5).

This paper poses the central question, "Is energy poverty affecting African-Americans relatively more than other households?" by using three different energy poverty measurements, namely ten-per cent (10%), two-median (2XM) and low income-high costs (LIHC) approaches following previously used and well-reported measures in the literature (Dogan et al., 2021; Siksnelyte-Butkiene et al., 2021). The first two indicators are similar in that they define energy poverty as excess spending on energy beyond a certain threshold. Thus, a household is energy-poor when its share of energy expenses relative to its disposable income (income minus taxes) is higher than 10% (threshold is fixed and independent of country-specific patterns). A household is considered energy poor if the share of energy expenses relative to its disposable income (income minus taxes) is more than twice as large as the national median in the current year (where the threshold changes each year). By contrast, the LIHC indicator assumes that energy poverty refers to poverty caused by the costs of adequate energy services (Siksnelyte-Butkiene et al., 2021). So, a household is energy poor following the LIHC indicator if the energy costs to achieve adequate energy services are above the median level. If they spend this amount (if the energy costs of these households are higher than those of the median household), their residual income is below the official poverty line (push them below the threshold of poverty).

Moreover, this study contributes to the scarce literature that uses micro-level data to examine the impact of the race on energy poverty (Churchill and Smyth, 2020; Downer et al., 2021; Graff et al., 2021; Wang et al., 2021). The scarcity of such studies is surprising since the issue of race dominates in recent world events, especially in the USA and energy poverty is one of the

Sustainable Development Goals. Also, the energy transition has been reported recently as a field needing to consider race issues (Newell, 2021). Additionally, we contribute to different literature strands: energy poverty analysis at the micro-scale weighing recent data and the second, that of the determinants of energy poverty besides socioeconomic indicators (Churchill and Smyth, 2020; Dogan et al., 2021). Finally, the present study uses health and income as mechanisms, differently from previous race-energy poverty nexus studies (Churchill and Smyth, 2020; Wang et al., 2021). Oster's bound estimates (Oster, 2019) are applied for each energy poverty measure used to surpass unobservable selection and omitted variable bias, as in Dogan et al. (2021). Besides, additional robustness check, we distinguish between gender effects and include different covariates.

The rest of the article develops as follows. Section 2 presents the framework and motivates the discussion of the nexus between race and energy poverty, explaining why African Americans in the USA have such a relevant role in this debate. Section 3 briefly presents the data and methodologies implemented, while section 4 introduces empirical results and discusses them in the light of policy implications. Robustness checks are provided in section 4 as well. Finally, section 5 concludes this work.

2. The nexus of race and energy poverty

The energy sector was declared to face three significant transformations (González-Eguino, 2015) in the forthcoming years. These have been identified by González-Eguino (2015) as climate change, supply security, and energy poverty. Recently, the scientific literature has deeply analysed the same transformations (to mention a few, Zhao et al., 2021; Nguyen and Nasir, 2021; Dogan et al., 2021). The United Nations Sustainability Development Goals (SDGs) emphasise the need to eradicate poverty and energy poverty (SDG7) to reduce the energy poverty gap for electricity access; Mastrucci et al., 2019). But what is energy poverty? Many definitions emerged in the literature, and the lack of consensus is mainly due to its different possible measurements (Siksnelyte-Butkiene et al., 2021). Reddy (2000) aims at providing a broad and all-inclusive definition of "the absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe and environmentally benign energy services to support economic and human development".

2.1. The energy poverty-race relationship

Bednar and Reames (2020) define as energy-poor those households that cannot meet basic energy needs (Hérnandez, 2016), recognising its prevalence in the USA. Furthermore, it is pointed out that current metrics and measures depend on government resources distribution and the number of vulnerable households receiving support, not focusing on household well-being or reducing general energy-poverty levels (Bednar and Reames, 2016). Many have been the pointed factors that influence energy poverty or justify energy insecurity. However, these mainly concern sociodemographic and socioeconomic conditions (Zhao et al., 2021). Fewer have been attempts to consider other factors besides the common socioeconomic ones while using microdata, namely household survey data. These include, and recently, ethnic diversity (Churchill and Smyth, 2020), financial inclusion (Koomson and Danquah, 2021; Dogan et al., 2021), health (Churchill and Smith, 2021), racial disparities (Wang et al., 2021), income inequality (Bardazzi et al., 2021), and housing conditions and energy burdens (Dogan et al., 2021; Graff et al., 2021).

As already stated in the introduction, if race and poverty have a well-reported relationship in the literature, with gender and race gaps reinforced by the recent pandemic (Samuel et al., 2021), imposing health restrictions and effects (Bambra, 2021), the existent ties between race and energy poverty are according to expectations. It is pointed out by Bambra (2021) significant inequalities in health by socioeconomic status, race/ethnicity, gender, and several other axes of social inequality in the USA. Furthermore, Bednar and Reames (2020) follow Drehobl and Ross (2016), revealing huge disparities in energy poverty. It is stated that urban and rural low-income households' energy expenses represent three times more (in income terms) than those of non-low-income households. Also, "low-income, African-American, Latinx, multifamily and renter households" face higher energy burdens (Drehobl and Ross, 2021; Bednar and Reames, 2020, p. 432). Complementarily, Bednar et al. (2017) provide evidence that supports energy efficiency assistance targeting while recognising the significant role of race, ethnicity, place, and class in energy poverty. Hérnandez (2016) defines energy poverty (energy insecurity) as a three-dimensional construct affected by the interconnection between economic, physical, and behavioural factors.

The first authors to explore the link between ethnic diversity and energy poverty used 12 waves of the Household, Income, and Labor Dynamics in Australia (Churchill and Smyth, 2020), finding a positive link and having trust as an essential channel. The most recent studies that we know of analysing race as a driver of energy-related concerns are Graff et al. (2021) and Downer et al. (2021) for the Wisconsin state. Graff et al.'s (2021) result point that Black and Hispanic households are more energy insecure than white households. They further highlight that housing conditions and energy burdens only explain a small part of the relationship between race and energy insecurity, leaving open the answer to why households of colour experience higher energy insecurity rates and the mechanisms behind these disparities. Wang et al. (2021) state that African-American households are more vulnerable than white and Asian households. These findings were derived from the 1990, 1997, 2005, and 2015 American Community Survey and allowed them to conclude that one-third of them lived in energy poverty by 2015. Graff et al.'s (2021) conclusions were derived from an initially collected survey of 2000 adults in Louisiana between 30 April and June 2020.

Wang et al. (2021) concentrate their analysis on exploring racial disparities in energy poverty in the USA, concluding that African-American households are more vulnerable than white and Asians. The authors employ energy expenditure, energy consumption, and household income as mechanisms. The energy burden of different racial groups was found by Wang et al. (2021) to change significantly across energy types, end-user demands, and regions. They include the climate and household socioeconomic characteristics, as we do, but differently. To perform sensitivity checks, we exclude from the analysis those states in the USA where the African-American population exceeds 20%. Race is found to positively influence energy poverty while revealing higher adverse effects on health mechanisms than through income. However, health and income mechanisms indicate a decrease in energy poverty, which is higher for income.

When we consider the literature focusing on the energy consumption patterns of various ethnic groups and races, we see that racial differences can be associated with energy insecurity or poverty (Wang et al., 2021). The outcomes of Reames (2016) analysis in Kansas imply that urban housing choices are affected by racial segregation, which exposes Black and Hispanic groups to higher energy vulnerability. Drehobl et al. (2020) also note the vast difference of high energy burdens for Black, Hispanic and Native American groups, which spend a more significant proportion of their income on paying their energy bills. Interestingly, Adua and Sharp (2011) investigate the four waves of the Residential Energy Consumption Surveys in the U.S. and convey that African-Americans consume higher natural gas consumption, even after controlling the weather conditions, housing characteristics, energy efficiency investments, and other covariates of energy consumption. They suggested that further analysis is required to understand the differences in consumption for different ethnic groups. The U.S. stands as a beautiful example for investigating the energy poverty-race relationship resulting from high diversity and segregation in the country. When we analyse the literature, there are also a limited amount of papers focusing on ethnic differences. Paudel (2021) links ethnic fractionalisation with increased E.P. among Nepalese households with higher E.P. impacts among low-caste groups. He further communicates that income has a significant role in mediating the ethnic differences on E.P. in Nepal. Yet, overall, irrespective of the context, ethnic diversity and race are associated with destabilised conditions and higher E.P. for minority groups.

2.2. Why African-American households?

African Americans are just one of the multiple racial groups found in the U.S. But the Black population of the United States is growing (roughly 14% of the country's population in 2019) (Pew Research Center, 2021). When we consider the US Black population, we need to consider their three demographic subgroups: single-race non-Hispanic, multiracial non-Hispanic, and Black Hispanic people (Pew Research Center, 2021). From all the racial diversity in the U.S., the Black community is one of the highest after the Hispanics. However, America has a multi-ethnic and multicultural society nowadays (Perez and Hirschman, 2009; Lewis et al., 2020; Wang et al., 2021), which will reshape racial and ethnic boundaries up to 2050. Thus, African-Americans are still one of the largest ethnic groups in the U.S. Nowadays, this community is essentially the descendants of enslaved people brought from their African homelands (by the hands of Spanish and Portuguese people, mainly during the discoveries period). They were forced to work as enslaved people in the "New World", having limited rights. They were long denied economic, social, and political rights, which persist (Wright II and Merritt, 2020), even though they made essential and long-lasting contributions to American history and culture (Lewis et al., 2020).

According to the Pew Research Center (2021), in 2019, the South is the region with the highest share of the country's Black population (56%), followed by the Midwest and Northeast, both accounting for 17% of this population, and lastly the West with 10% of African-Americans. In the U.S., Texas has the largest Black state population (3.9 million), followed by Florida (3.8 million), Georgia (3.6 million), New York (3.4 million), and California (2.8 million). Jointly, these five states hold 37% of the national Black population (Pew Research Center, 2021). Additionally, in 2019 Black bachelor's degree holders more than doubled since 2000 (from 2% to 4.1%). The same applies to holders of Masters and higher (1% in 2000 up to 2.6% in 2019). Despite the promised "New World" immigrant wave, in 2019, the number of Black immigrants has almost doubled since 2000 (2.4% to 4.6%), being most of the Caribbean and African origin, with a growing tendency in the upcoming years. As well, and despite the ever-increasing educational level, the Pew Research Center (2021) highlights that since 2000, the US Black population has not seen significant increases in the median household income. This increases the disparities in the racial-poverty nexus, turning the African-American group into an exciting case study in the energy-poverty-racial nexus.

Income inequality within the Black community in the U.S. is still one of the widest within this significant racial or ethnic group (Pew Research Center, 2021). African-Americans have a higher probability of living in older, energy-inefficient homes (Lewis et al., 2020). Their homes present structural deficiencies, outdated appliances, and faulty energy systems (Lewis et al., 2020). Considering, thus, the broad American country, African-Americans burden of energy insecurity is disproportionate, unable to meet household energy needs adequately, increasing costs and decreasing comfort, will all the adverse effects on physical and mental health that living in these conditions drive (Lewis et al., 2020; Monk, 2020; Chapman et al., 2021).

As highlighted previously, African-Americans segregated living conditions (income inequality, wealth gaps, entrenched racial residence) reduce their ability to escape this vicious cycle (Lewis et al., 2020; Wang et al., 2021; Churchill and Smyth, 2020; Buch et al., 2021). The recent Covid19 pandemic further exacerbated the oppression and disenfranchisement of African-Americans (Wright II and Merritt, 2020). This community needs to be uplifted in many areas due to rooted socioeconomic living conditions (health care inequality, segregation, underrepresentation in economic, social, and political terms) (Wright II and Merritt, 2020; Monk, 2020; Churchill and Smyth, 2021).

3. Data and Methodology

The dataset of the paper is derived from the Survey Research Center Panel Study of Income Dynamics (PSID) 2019 Survey, which is the world's longest-running, USA representative household panel survey data collected since 1968. We specifically focus on the most recent microdata from 2019. For more details https://psidonline.isr.umich.edu/. The total sample consists of 9,043 households. Table 1 describes the variables and summary statistics for the sample. 32.1 per cent of the respondents are females, and the average age of the respondents is 46.41 years old. The average of the respondents' education level in years is 13.42 years. Forty-four per cent of the respondents are married, and the average size of the households is 2.58 people. Among the sample, 70.4 per cent are employed, and 50.4 per cent own a house. 39.2 per cent of the respondents are African-Americans.

3.1 Energy poverty

Considering the previous research, three different energy poverty measures are used (Churchill and Smyth, 2020; Dogan et al., 2021). The first measure adopted in the paper is the Low Income-High Cost (LIHC), which focuses on the low-income class of households and high energy costs. LIHC categorises households with energy costs exceeding the energy cost threshold and with an income level below the income threshold as energy poor. The second measure of energy poverty used in this paper is the 10 per cent approach. This measure compares the percentage of energy expenditure in the total budget of households. The household is considered energy poor if energy expenses exceed a certain threshold level. The most commonly used threshold level in the literature is 10 per cent (Boardman, 1991; Thompson et al., 2017), but obviously, this threshold level subjectivity forms the approach's weakness. The measure is susceptible to energy prices. The arbitrary selection of the threshold level and the ignorance of the household income level are the deficiencies of the 10 per cent approach (Heindl, 2015). The third measure is the two times median approach (2xMedian approach). This measure regards households in energy poverty if the percentage of income spent on energy expenditures is higher than twice the national median (Liddell et al., 2012).

According to the outcome, 12.5 per cent, 28.7 per cent, and 9.3 per cent of the sample is energy poverty using the 10% approach, 2Xmedian approach, and LIHC approach, respectively. The differences in E.P. levels of households are striking, but these differences are also noted in the literature. Ntaintasis et al. (2019) suggest that the outcomes of the different approaches might point to different results. A household considered energy-poor by one method might not be energy-poor by another method.

Table 1: Summary statistics

Variable	Description	#Obs	Mean	Median	Std. Dev.
	Poverty-related characteristics				
10%	Equals 1 if greater than 10%	9,043	0.125	0.0	0.331
2xMedian	Equals 1 if greater than two times median	9,043	0.287	0.0	0.452
LIHC	Low-income High-cost	9,043	0.093	0.0	0.291
Hincome	Annual earnings of household in $US	9,043	77,253	56,000	78,045
Henergy	Annual expenditure on energy in $US	9,043	1844	1788	1643
	Household characteristics				
Female	Equals 1 if household is female	9,043	0.321	0.0	0.467
Age	Equals age of household in years	9,043	46.41	43.0	16.35
Edu	Education level of household in years	9,043	13.42	13.0	2.61
Married	Equals 1 if household is married	9,043	0.440	0.0	0.496
Hsize	Equals number of people living in home	9,043	2.580	2.0	1.509
Employed	Equals 1 if household is with a job	9,043	0.704	1.0	0.456
Own	Equals 1 if household is a home owner	9,043	0.504	1.0	0.495
Race	Equals 1 if household is African-Americans	9,043	0.392	0.0	0.488

3.2 Covariates

To deal with heterogeneity inherent in the data, we used the covariates of the household characteristics. In the analysis, we check for gender, age, education, marital status, employment status, and households' ownership of a house. Age is a significant factor that will influence tenure and experience; eventually, it has a crucial impact on the employment status and income level. On the other hand, it is related to cognitive development capabilities, and it may affect the energy consumption and energy-related decisions made by the households (Churchill and Smyth, 2020).

Gender, employment status, and education level have a significant effect on the employment conditions of the household. As the level of education increases, they are getting higher payment might increase. Moreover, higher education might be linked to increased awareness regarding housing insulation and/or energy efficiency (Dogan et al., 2021). Marital status and the ownership of a house affect the income level of households. Accordingly, these two factors have a crucial impact also on energy poverty.

3.3. Empirical methodology

First, we run OLS and logistic regressions on LIHC as an E.P. measure. It enables us to reflect diverse poverty dimensions such as income poverty and housing cost induced poverty. To evaluate the impact of household characteristics, including the ethnic race, we first run an OLS model as a baseline estimate:

$$EP_i = \alpha_0 + \alpha_1 RACE + \alpha_2 HC_i + \varepsilon_i \qquad (1)$$

Where E.P. represents the energy poverty level of the i^{th} household, RACE is a dummy variable: 1 if the participant is African-American households, HC means the household characteristics like age, gender, education, marital status, household size, employment and ownership of a house, and ε_i represents the error term.

After running the OLS, we estimate the E.P. equation using logistic regression. Logistic regression enables us to assess the likelihood of a certain event existing on the condition that the E.P. measure used in the regression is based on indicators. The model estimates the probability of specific outcomes. Y_i represents a random binary variable, equal to 1 if the respondent is energy poor and 0 otherwise. The probability of being energy poor π_i is expressed as $\pi_i = P(Y_i = 1) = P(Y_i^* > \theta)$ with Y_i^* the latent response. The following model is estimated:

$$Y_i = log\left(\frac{P_i}{1-P_i}\right) \alpha_0 \ + \alpha_1 HC_i + \varepsilon_i \qquad (2)$$

where Y_i^* represents the log of the odds ratio (*P_i=1* if the respondent is in energy poverty, and 0 otherwise according to the LIHC method), *H.C.* represents household characteristics, and ε_i represents the error term. The error term is assumed to follow a standard logistic distribution.

To evaluate the outputs of logistic regression, the odds ratio has to be calculated. Modelling a binary variable by applying logistic regressions, the logit transformation of the binary variable is assumed to have a linear relationship with the predictor variables, making the interpretations of the coefficients misleading. Odds are formed from probabilities and range between 0 and infinity (ratio of the likelihood of success and failure).

Robustness Checks

To deal with the endogeneity due to omitted variable bias bounding approach of Oster (2019) is adopted. The bound test extends the common methods to deal with coefficient movements following the inclusion of controls. Following the bounding approach of Oster (2019), it is necessary to determine two significant pieces of information to estimate the bounds. The first information is related to the relative degree of selection on observed and unobserved variables, the value of δ. The second information is associated with the R^2 derived from a hypothetical regression of the treatment variable on observed and unobserved factors (R^2_{max}). δ should be arranged as one, implying that the selection of observables and the unobservable variables are identical. R^2_{max} should be set to $Min\{1,1,3\widehat{R^2}$ where $\hat{R}^2$is calculated from baseline regressions. The R^2 and the coefficients changes are significant indicators to assess the robustness of the estimates.

4. Empirical Results

Table 2 presents the OLS and Logit results of the model specifications as presented in the previous section. In these estimations, we used the LIHC indicator for measuring energy poverty, providing thus a baseline. We observe that race is a positive contributor to Energy Poverty (Columns 1 and 3) and that the coefficient demonstrating the relationship is statistically significant (Columns 2 and 4). From Column 1, the estimation results show that a standard deviation increase in race is associated with an increase of 0.398 standard deviations in the number of households with energy costs exceeding the threshold with an income level below the threshold. From Column 3, the OLS estimation suggests that one standard deviation increase of race is associated with a 0.0028 standard deviations increase in the number of households with energy costs exceeding the threshold with an income level below the threshold. These findings confirm the expected relationship between race and energy poverty, showing a higher probability of African-American households living under energy poverty conditions (measured in LIHC). Overall, the control variables of Table 2 confirm the prior expected signs as per theory: the gender of the head of the household and the household size increases the probability that the household is classified as energy-poor. In contrast, the age of the head of the household, the marriage status, the ownership and employment level are all negative contributors to energy poverty.

Table 2: Race and energy poverty (results from LIHC)

	Logit		OLS	
	Coeff.	Robust Std. Error	Coeff.	Robust Std. Error
Race	**0.398*** **	**0.085**	**0.028*** **	**0.007**
Female	0.505***	0.095	0.052***	0.009
Hsize	0.195***	0.028	0.020***	0.003
Age	-0.018***	0.003	-0.002***	0.000
Married	-0.997***	0.130	-0.051***	0.008
Own	-0.562*	0.100	-0.034***	0.007
Employed	-1.581***	0.090	-0.153***	0.009
Edu	-0.209	0.017	-0.016***	0.001
Constant	1.655***	0.289	0.456***	0.027
R^2	0.2160		0.1360	

Note: * and *** represent 10% and 1% level of significance.

The positive relationship between Race and Energy poverty measured in LIHC is confirmed again when the studied sample is divided according to gender (male/female) reported in Table 3. A standard deviation increase of race is associated with 0.298 (female) and 0.551(male) standard deviations of female and male-headed households with energy costs higher than the threshold and income levels below the threshold based on the Logit estimations. The OLS estimation results agree with the findings, albeit the parameters are smaller in magnitude and insignificant for the female grouping. It should be noted here that although race is a positive factor in energy poverty in both groups, the coefficient is lower for the Female-headed households than the Male headed ones, showing that female-headed households are more resilient to energy poverty. This outcome is in line with Dogan et al. (2021) and Koomson and Danquah (2021).

Table 3: Race and energy poverty: Male-Female (results from LIHC)

	FEMALE			
	Logit		OLS	
	Coeff.	Robust Std. Error	Coeff.	Robust Std. Error
Race	**0.298***	**0.115**	**0.018**	**0.013**
Covariates included?	YES		YES	
Obs#	2,903		2,903	
R^2	0.1525		0.1388	
	MALE			
	Logit		**OLS**	
	Coeff.	Robust Std. Error	Coeff.	Robust Std. Error
Race	**0.551*****	**0.122**	**0.031*****	**0.007**
Covariates included?	YES		YES	
Obs#	6,140		6,140	
R^2	0.2172		0.1064	

Note: * and *** represent 10% and 1% level of significance.

From Table 4, we find that the choice of measurement indicator of energy poverty does not affect the positive relationship between Race and Energy poverty. From the Logit estimation, a one standard deviation increase of race is associated with an increase of 0.624 standard deviations of households that spent 10% or less in energy as a share of their total budget and an increase of 0.499 standard deviations of households in the *two times median approach*. These results indicate the robustness of the positive relationship between Race and Energy poverty, as confirmed in the baseline of Table 2.

Table 4: Race and energy poverty (results from 10% and 2Xmedian)

	Logit		OLS	
Energy poverty indicator: 10%	Coeff.	Robust Std. Error	Coeff.	Robust Std. Error
Race	**0.624*** **	**0.075**	**0.060*** **	**0.008**
Covariates included?	YES		YES	
R^2	0.1696		0.1276	
	Logit		**OLS**	
Energy poverty indicator: 2Xmedian	Coeff.	Robust Std. Error	Coeff.	Robust Std. Error
Race	**0.499*** **	**0.054**	**0.091*** **	**0.010**
Covariates included?	YES		YES	
R^2	0.1236		0.1434	

Note: *** represents a 1% level of significance.

4.1. Robustness checks and sensitivity analysis

This section provides the outcome of a battery of robustness and sensitivity tests to confirm our initial hypothesis and baseline results. First, to further explore the robustness of the estimations, we run the same regressions as in the baseline for the three chosen indicators of energy poverty using Oster's (2019) bound testing approach. Table 5 presents the findings in agreement with the positive association of race and energy poverty.

Table 5: Oster (2019)'s bound estimates

	LIHC	10%	two-median
Race	**(0.010, 0.083)**	**(0.047, 0.109)**	**(0.058, 0.161)**
Covariates included?	YES	YES	YES
Diagnostics			
Observations#	9,043	9,043	9,043
R^2	0.136	0.128	0.143

Next, we investigate the results by excluding states with a high African-American share of the population, potentially driving the estimation results. We exclude the states with an African-American population proportion greater than 20% (District of Columbia, Mississippi, Louisiana, South Carolina, Georgia, Maryland, Alabama, and North Carolina). Table 6 shows that the positive relationship of race and energy poverty remains for all three different estimators of energy poverty. As expected, the coefficients are lower in magnitude but still statistically significant. These results indicate the potential to generalise our results and minimise a sampling bias. We find, thus, that our results are robust to the exclusion of these states, ensuring that they are not the ones that drive the baseline results.

Table 6: Exclusion of specific states (OLS estimates)

	LIHC	10%	two-median
Race	**0.022*** (0.007)**	**0.054*** (0.008)**	**0.092*** (0.011)**
Covariates included?	YES	YES	YES
Observations#	7,518	7,518	7,518
F-stat	85.57***	95.23***	157.44***
R^2	0.1288	0.1174	0.1326

Note: *** represents a 1% level of significance. Robust standard errors are in parenthesis.

4.2. Channels of influence

This section explores the potential role of health and income in the examined relationship. To do so, firstly, we establish the relationship between race and the two mechanisms. If this relationship is established, we proceed with estimating the impact of race and each of the mechanisms on energy poverty. Table 7 confirms that health and income are correlated (negative and statistically significant for both variables) with race, and hence, they can qualify as potential channels of influence.

Table 7: Impact of Race on mechanisms

	ln(health)		ln(income)	
	Coeff.	Robust Std. Err.	Coeff.	Robust Std. Err.
Race	**-0.253*****	**0.043**	**-0.138*****	**0.019**
Covariates included?	YES		YES	
Observations#	6,057		7,407	
F-stat	181.45***		67.91***	
R^2	0.2166		0.4625	

Note: *** represents a 1% level of significance.

Table 8 shows that the inclusion of income and health variables as addition as covariates reduces the magnitude of the coefficients. Health and income are associated with a decline in race; they are a potential channel through which race influences energy poverty.

Table 8: Impact of mechanisms on energy poverty

	Coeff.	Robust Std. Err.	Coeff.	Robust Std. Err.
Race	0.045***	0.003	0.029***	0.007
ln(income)	---	---	-0.130***.	0.006
ln(health)	-0.019***	0.008		
Covariates included?	YES		YES	
Observations#	6,057		7,407	
F-stat	50.77***		101.36***	
R^2	0.2145		0.2569	

Note: *** represents a 1% level of significance.

5. Conclusions and policy suggestions

The main purpose of this study is to examine the relationship between energy poverty and race, with a particular focus on U.S. African-American households. The study used data from the Panel Study of Income Dynamics (PSID), the world's longest-running, USA representative household panel survey. PSID has collected data over the same families and their descendants since 1968. Different energy poverty measurements are used following previously used measures and are well reported in the literature (Dogan et al., 2021; Siksnelyte-Butkiene et al., 2021). Dependent on data availability, energy poverty is measured objectively in various ways, namely, the expenditures based, the minimum income standards, and the Low Income-High Costs (LIHC) approaches, for robustness and sensitiveness check.

The study's findings suggest a robust positive relationship between race and energy poverty. The baseline regression results of the Logit estimation suggest that one standard deviation increase in race is associated with a 0.398 standard deviations increase in Energy Poverty measured by LIHC. The overall positive and statistically significant association remains strong throughout the analysis, regardless of the proxy of energy poverty, excluding certain states with a high share of the African-American population and different covariates.

The limitation of many race-related studies is that the policy recommendations are limited in the proposal of policies against discrimination with equitable instruments and programs. This study also suggests that such programs would be beneficial in ensuring the breakage of the link between race and energy poverty by providing preferential discounted rates and easier access to energy to specific demographics of the population. At least ending with the housing segregation of African-Americans in the U.S. would be a way to surpass these difficulties and decrease energy poverty. As Lewis et al. (2020) point out, their homes present structural deficiencies, outdated appliances, and faulty energy systems, being their energy insecurity burden heavier. Thus, a vicious cycle will be hard to support by vulnerable ethnic groups, exacerbating their inability to escape if appropriate political measures are not taken (Wang et al., 2021; Churchill and Smyth, 2020). Perhaps promoting renewable energy communities would be a solution, or even provide access at affordable costs to financing promoting the prosumers behaviour of these household-communities.

This study also provides important implications of the health and income level for these population groups. The estimation results showed that income and health could be qualified as potential mechanisms. By improving them, the race can become less critical in energy poverty eradication. Since 2020 this group has not seen significant increases in median household income (Pew Research Center, 2021), and income inequality is proved to aggravate energy poverty in this work. Therefore, Race here means that people cannot meet household energy needs appropriately and adequately, increasing costs and decreasing comfort. This is reflected in lower access to health care, with all the adverse effects on physical and mental health (Chapman et al., 2021; Lewis et al., 2020; Buch et al., 2021; Churchill and Smyth, 2021).

Another exciting result of the study was that the only estimated parameter between race and energy poverty that was statistically insignificant was that for the female sub-group. The lack of a relationship between female race and energy poverty can direct us to a different kind of problem, that of women's discrimination and gender inequality regardless of race, that needs to be addressed by policymakers. Several precautions must ensure equal treatment for income and education opportunities among gender groups for different ethnicities.

Recently, Memmott et al. (2021) concluded that Black and Hispanic households are more vulnerable to energy insecurity and face utility disconnection. This fact is associated with their characteristics, such as being households with young children, requiring electronic medical devices, and dwelling in inefficient or poor conditions. The COVID-19 pandemic has been argued to exacerbate the overall incidence of energy insecurity. Still, outstanding energy bill debts remain at very high levels in the U.S. and worldwide, by the way. In January 2022, the Heating and Cooling Relief Act (Heating and Cooling Relief Act, 2022), with the specific purpose of ending energy poverty in this country. The bill would significantly increase funding for the government's Low Income Home Energy Assistance Program (LIHEAP) ($3.8 billion to $40 billion). These measures have been recently created as the literature points to the exacerbation of energy insecurity and poverty in the U.S. during the pandemic (Memmott et al., 2021; Bednar and Reames, 2020).

One of these measures involves ensuring that no eligible family of four would pay more than 3% of their income on home energy. Usually, low-income families typically spend about 8.6% of their household income on home energy, compared to just 3% for higher-income households. It also expands the program to assist moderate-income families by raising the income eligibility ceiling from 150% of the poverty level (or 60% of state median income) to 250% of the poverty level (or 80% of state median income). Finally, the bill would provide emergency funds to help the more vulnerable families pay higher energy bills due to increased air-conditioning needs during extreme heat or cool (Scheier and Kittner, 2022). As our results allowed us to observe, African-American households are among the most vulnerable in the U.S. Scheier and Kittner (2022, p.1) argue that "more than 5.2 million households above the Federal Poverty Line face energy poverty, disproportionately burdening Black, Hispanic, and Native American communities", validating our results. The authors recommend the United States develop a more inclusive federal energy poverty categorisation, increasing assistance for household energy costs. If approved, the Heating and Cooling Relief Act (2022) will decrease disparities among races within the country. It could also serve as a way to signal significant changes needed worldwide. In opposition to simple compensation measures that have been at the centre of the U.S. policy strategies for energy poverty alleviation, as the recent act, Lee et al. (2021) argue that assistance like this cannot be a long-term solution. The authors say that empowerment measures can create lasting improvement in all three categories of energy capabilities. The emphasis is on implementing energy-saving measures and developing community-based energy options for at-risk households. Besides, it has been demonstrated that low-income African-American households face energy poverty. Urgent attention should also be provided to the increasing number of white households in energy poverty (Memmott et al., 2021; Wang et al., 2021; Scheier and Kittner, 2022).

The lack of adequate energy services is just one way to express gender inequalities (Listo, 2018). Gendered socio-spatial vulnerabilities to energy poverty have been gathered in Robinson (2019) into five dimensions for England. These are unpaid reproductive, caring, or domestic roles; exclusion from a productive economy; lack of social protection during life course; susceptibility to physiological and psychological health impacts; and coping and helping others (dependents) to cope. All these dimensions have been identified in the sample, and this study's results are not only for race but gender, too. Therefore, energy poverty is not just a race problem within the African-American community in the U.S. but a general vulnerability issue (Memmott et al., 2021; Wang et al., 2021; Scheier and Kittner, 2022). Thus, perpetuating poverty, segregation, exclusion, entrenched racial residence, low income and earnings, vulnerable health care system access, and socio-political-economic underrepresentation will only aggravate the racial-energy poverty nexus. This demands urgent policy measures and appropriate political intervention from policymakers to erase poverty and energy poverty by consequence. The Heating and Cooling Relief Act (2022) could be a valuable response in this sense, as will empowerment measures (Lee et al., 2021).

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