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Axiom of the relative income hypothesis and household energy choice and consumption in developing areas: Empirical evidence using Verme model

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ABSTRACT

According to the relative income hypothesis, consumption behavior of households does not depend solely on their absolute income but also relatively on other peoples' income and consumption behavior. Households try to maintain their consumption pattern in such a way to meet the average consumption standard of their community. This study was conducted with the major aim of testing the validity of this axiom in relation to the household energy choice and consumption in the context of developing countries. In total, 540 households were utilized as the samples of the study. The study used both statistical and econometric (Verme model) tools. Both the cooking and lighting aspects of household energy sources were examined separately. The study found that all the various tests methods confirmed the validity of the axiom of relative income hypothesis in relation to household energy choice and consumption. Therefore, if the policy makers of developing areas take this aspect into consideration, it will simplify the process of making and implementing policies for shifting households away from using traditional biomass energy sources to modern, clean sources of energy.

Introduction

In 1949, Duesenberry came up with the theory associated with the relative income hypothesis which was an alternative to Keynes's absolute income hypothesis. According to the relative income hypothesis, consumption behavior of households does not depend solely on their absolute income but also relatively on other peoples' income and consumption behavior. Households try to maintain their consumption pattern in such a way to meet the average consumption standard of their community. That is, they try to keep up with the Joneses, as households and individuals normally compare themselves to those who surround them and those having similar characteristics (Hounkpatin, Wood, Brown, & Dunn, 2015; Kosicki, 1987). This argument of community and relative impacts on the pattern of consumption behavior of individuals and households, was popularized by the work of Duesenberry (1949), though it had been argued by scholars earlier than Duesenberry. For instance, Marx (1847) argued that "*A house may be large or small; as long as the neighboring houses are likewise small, it satisfies all social requirement for a residence. But let there arise next to the little house a palace, and the little house shrinks to a hut*". In the same vein,

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Veblen (1899) in his concept of consumption and leisure emphasized the relevance and importance of individuals' relative positions in society in shaping their consumption behavior. However, despite this argument being popularized by Duesenberry (1949), it was immediately marginalized by the emergence and popularity of the permanent income hypothesis which resulted in the axiom of the relative income hypothesis (RIH) being only seldom empirically analyzed for some decades despite its policy relevance (Brown, Gray, & Roberts, 2015; Kosicki, 1987; Verme, 2013).

Over the last three decades, many studies have been carried out to empirically test the theory of the relative income hypothesis in different aspect of consumption behavior of individuals and households: household saving behavior (Kosicki, 1987), individual health and mortality (Mangyo & Park, 2011), household commodity consumption (Khan, 2014), individual performance on the workplace and job satisfaction (Card, Mas, Moretti, & Saez, 2012; Torgler, Schmidt, & Frey, 2006), depression (Hounkpatin et al., 2015; Cuadrado & Long, 2011), and life satisfaction and well being (Brown et al., 2015; Carbonell, 2005; McBride, 2001; Senik, 2003, 2008). However, none of these studies considered the aspect of household energy choice and consumption. Household energy consumption is one of the most important aspects of household consumption. It is a commodity that is vital for the existence of modern household living (Eakins, 2013). A direct improvement in energy services would allow the poor to enjoy advances in living standards both in the short run and the long run (Lee, 2013; Reddy, 2004). It is the key factor to improve the mode of living for the rural population (Ganchimeg & Havrland, 2011). Moreover, encouraging households to switch to efficient energy would lead to the consumption of less fuel per meal and less time spent gathering fuel, which could be used in other activities such as attending school and other income-generating activities (Yamamoto, Sie, & Sauerborn, 2009). Efficient energy provides easy access to education, health care, and household resources. Children who do not have to collect bio fuels can attend school (Smith, Rogers, & Cowlin, 2005). Switching to efficient fuels could also free up time for women to engage in income-generating pursuits (Wilkinson, Smith, Joffe, & Hainess, 2007). This study was conducted with the main aim of testing the axiom of the RIH as it is applies to the aspect of household energy choice and consumption. The underlying rationale here was to encourage households to shift from the use of less clean energy sources to the adoption of cleaner energy sources. Figure 1 indicates the relationship between the pattern of household energy choice and its impact on the general welfare.

Figure 1 indicates the relationship between the axiom of the RIH and the household energy choice. The components of the RIH can be categorized into three main instruments; income, the reference category (neighborhood

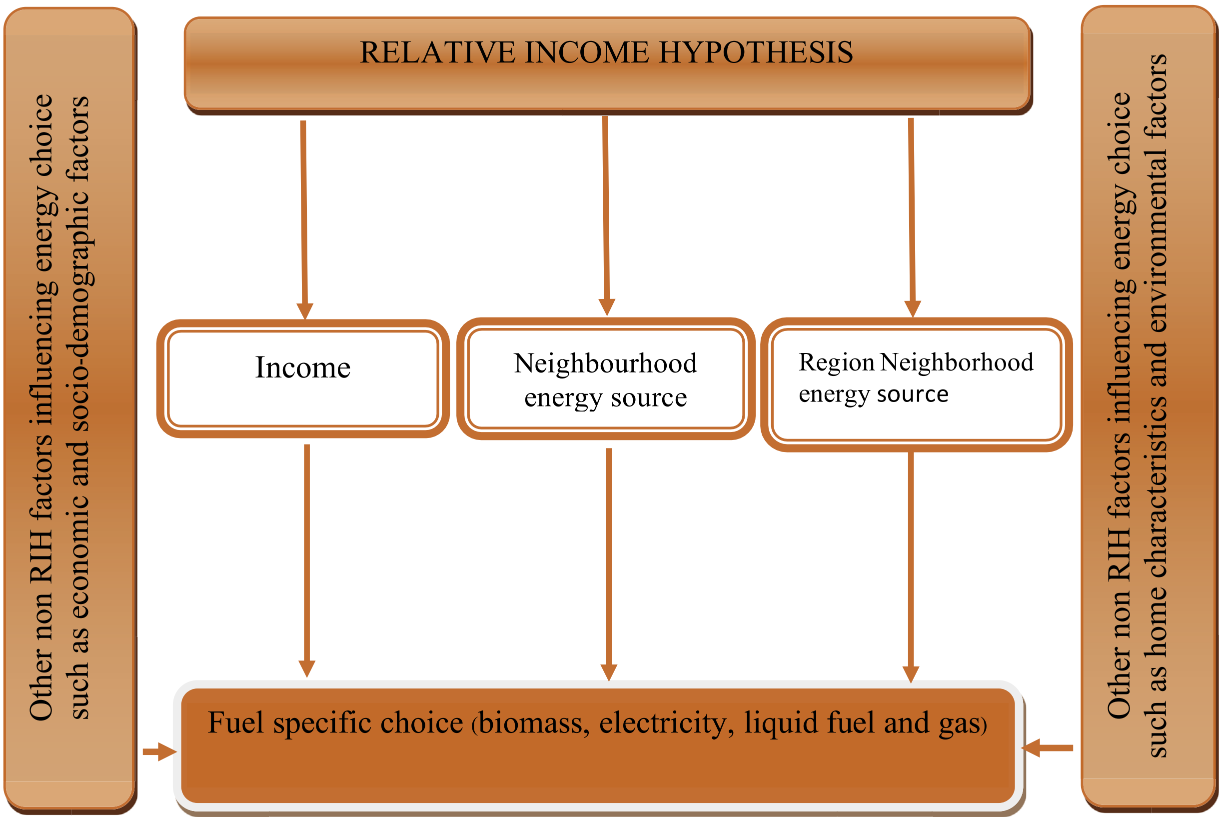

Figure 1 Relative income hypothesis and the household energy choice
Source: Modified from Danlami, Islam, and Applanaidu (2015)

consumption pattern) and the interaction of region and the reference category. Based on the diagram above, these three instruments of relative income hypothesis have direct impact on the nature of the household energy choice and consumption. The type of energy that is consumed by the households has its own impacts. When the households use modern, clean energy like electricity and gas, on average there will be an improvement in the general welfare. On the other hand, the use of inefficient energy sources like biomass fuel affects both the environment and the general public welfare.

Energy Consumption in Bauchi State

Bauchi State is the most populous state with the lowest modern energy use in Nigeria (NBS, 2012). There is a high rate of firewood use as the main source of fuel for many households in the State. The average rate of modern fuel use in the State is far lower than the national average. The rate of fuelwood use in the State, is more than 90 percent, which is higher than the urban national average of about 40 percent and the whole national average of about 70 percent (NBS, 2012). This rampant use of firewood has posed negative impacts to the inhabitants of the State such as the systematic destruction of the State's forest reserves and woodlands (AY, Ibrahim, Hamid, & Haruna, 2011). Furthermore, the environmental problems in the State, such as soil erosion and the persistent desertification, are the consequences of the felling of trees. The Bauchi State government argued that the State loses on average one square kilometer of land area annually because of desertification due to the high rate of felling trees for cooking fuel and other relevant uses (Ergun & Jun, 2011). The total estimated deaths due to indoor air-pollution-related diseases as a result of the high rate of biomass fuel use is 3,500 per year (NBS, 2012). Therefore, analyzing the patterns of household energy use in Bauchi State can enable the relevant authorities to have a clear picture and understand the factors that can shape the pattern of household energy choice in the State in order to encourage the households to adopt modern energy sources. This contributes to the process of government efforts in the attempt to curtail the excessive and widespread use of firewood as the major source of household fuel energy in the State. Though there have been some studies (Danlami, Applanaidu, & Islam, 2017a, 2017b) on household energy consumption in Bauchi State, these are completely silent on the relevance of the axiom of the relative income hypothesis and household energy consumption. Therefore, this study conducted an empirical test of the relative income hypothesis and household energy consumption in developing areas using Bauchi State as the case study.

Literature Review

Empirical Tests of Relative Income Hypothesis

Studies have tried to conduct an empirical test of the RIH on different aspect of consumption behavior of individuals and households. For instance, Brown et al. (2015) confirmed that the argument of RIH is relevant in explaining life satisfaction and that life satisfaction decreases as relative income increases. In the same vein, Clark and Oswald (1996) concluded that the satisfaction of workers has an inverse relationship with their comparative wage rates. However, contrary to these assertions, Senik (2003) found that the income of the reference group exerts a direct positive influence on individual satisfaction. Moreover, Carbonell (2005) concluded that the reference group income is almost as important as own income for the happiness and well being of individual. Furthermore, the empirical test of the relative income hypothesis by Senik (2008) indicated that the average income in an individual's occupational group influences negatively the individual's subjective well being in the old European countries, whereas in post transition economies, this correlation is positive.

Additionally, Kosicki (1987) conducted a study with the main aim of carrying out an empirical test of the RIH. The result strongly supported the hypothesis that rank has a significant impact on determining the rate of savings. Further analysis of the study indicated that rank has a significant impact on the savings rate even after allowing for the effect of differences in the level of permanent income. Lindley and Lorgelly (2005) conducted an empirical test of the RIH in relation to the self-reported health of individuals with a view to determining its validity over time. The conclusion was that there is an absence of a significant association between self reported health and the measures of inequality and therefore, the RIH does not exist over time and does not exist within Britain. Contrarily, the study by Mangyo and Park (2011) indicated the validity of the RIH in relation to individual self deprivation and health. Furthermore, empirical testing of the consumption function under the argument of the RIH by Khan (2014) in northern Pakistan validated the relative income hypothesis. The study concluded that farm household consumption expenditure is not only influenced by disposable income but also by the consumption pattern of other households. In addition, other studies (Card et al., 2012; Torgler et al., 2006) tested the applicability of the relative income hypothesis to individual performance in the workplace and on job satisfaction. They found validity of the concept of the RIH in relation to performance in the workplace and on job satisfaction.

However, though the studies that conducted an empirical test of the RIH used different aspects of individual and household life (as indicated earlier), they did not specifically test the relevance of this theory to household energy choice and consumption despite its policy being relevant to household energy choice and consumption. Therefore, this study serves as an additional contribution to the literature by conducting an empirical test of the RIH using a different aspect of household consumption.

Household Energy Use and Utility Maximization

Households mostly use energy not for direct satisfaction but for the purpose of producing another good or service. Usually, households use energy from different sources in order to maximize their satisfaction. This maximized satisfaction is usually attained at the equilibrium level of particular energy consumption. For instance, given a utility function of energy consumption as:

$$U = f(\in_c G_s\ \mathcal{L}_f\ \mathcal{B}_b) \tag{1}$$

subject to the following household budget constraint

$$\Upsilon = P_c \in_c + P_s G_s + P_f \mathcal{L}_f + P_b \mathcal{B}_b \tag{2}$$

where: U = utility, $\in_c$ = energy from electricity, G_s = energy from gas, $\mathcal{L}_f$ = liquid fuel, $\mathcal{B}_b$ = biomass fuel, Υ = household income and P = price of the relevant energy. In order to arrive at the maximum point of household energy utilization, we form the following Lagrangian multiplier function as:

$$L = f(\in_c G_s \mathcal{L}_f \mathcal{B}_f) + \lambda(\Upsilon - P_c \in_c + P_s G_s + P_f \mathcal{L}_f + P_b \mathcal{B}_b = 0) \tag{3}$$

Using equation (3), we can analyze the maximum point of utility for:

(i) Households that use only one of these energy sources
(ii) Households that use all of these energy sources

The equilibrium level of utility for households that use only one of these energy sources.

Assuming a households uses only electricity as it sole source of energy; the utility maximization point will be:

$$\frac{\partial L}{\partial \in_c} = f_c' - \lambda P_c = 0 \tag{4}$$

$$f_c' = \lambda P_c \tag{5}$$

Since the household utilizes only a single source of energy, $\lambda = 1$

$$f_c' = P_c \tag{6}$$

This is the point of maximized utility from using electricity where the marginal utility drive from consuming an additional unit of electricity is equal to the price of that unit of electricity. Any additional consumption of electricity above this level implies a decrease in the total utility while any electricity consumption below this level implies that the total utility from using the additional amount of electricity increases, until the above point is reached.

Assuming the households use only gas as their source of energy, the utility maximization point will be (partial derivation with respect to gas):

$$\frac{\partial L}{\partial G_s} = f_s' - \lambda P_s = 0 \tag{7}$$

$$f_s' = \lambda P_s \tag{8}$$

By definition; $\lambda = 1$, therefore the utility maximization point will be:

$$f_s' = P_s \tag{9}$$

where the additional satisfaction obtained from using an additional amount of gas is equal to its price.

For households that use only a liquid source of energy, the utility maximization point will be:

$$\frac{\partial L}{\partial \mathcal{L}_f} = f_f' - \lambda P_f = 0 \tag{10}$$

$$f_f' = \lambda P_f \tag{11}$$

Since $\lambda = 1$ (for households that use only one source of energy),

$$f_f' = P_f \tag{12}$$

Assuming the households use only a biomass energy source, the utility maximization point will be:

$$\frac{\partial L}{\partial \mathcal{B}_b} = f_b' - \lambda P_b = 0 \tag{13}$$

$$f_b' = \lambda P_b \tag{14}$$

Since $\lambda = 1$,

$$f_b' = P_b \tag{15}$$

that is, where the additional satisfaction obtained from using an extra bundle of biomass fuel is equal to the price of the additional bundle.

Utility maximization of households that use all four sources of energy together.

In this situation, the utility of using energy is maximized by consuming the energy up to the level where the ratio of extra satisfaction obtained from using the additional amount of energy to their prices are equal. Applying the earlier Lagrangian multiplier utility function and the constraints for energy use:

$$L = f(\in_c G_s \mathcal{L}_f \mathcal{B}_b) + \lambda(\Upsilon - P_c \in_c + P_s G_s + P_f \mathcal{L}_f + P_b \mathcal{B}_b = 0) \tag{16}$$

The partial derivatives with respect to each of the energy source are:

$$\frac{\partial L}{\partial \in_c} = f_c' - \lambda P_c = 0 \tag{17}$$

$$\frac{\partial L}{\partial G_s} = f_s' - \lambda P_s = 0 \tag{18}$$

$$\frac{\partial L}{\partial \mathcal{L}_f} = f_f' - \lambda P_f = 0 \tag{19}$$

$$\frac{\partial L}{\partial \mathcal{B}_b} = f_b' - \lambda P_b = 0 \tag{20}$$

$$\lambda = \frac{f_c'}{P_c} = \frac{f_s'}{P_s} = \frac{f_f'}{P_f} = \frac{f_b'}{P_b} \tag{21}$$

That is the utility maximization point for households that use all four sources of energy is for them to consume at the point where the ratios of the extra satisfaction from using an additional unit from each of the energy source to their prices are equal.

Data and Methodology

Because this paper involved a study of households at the micro level, this section contains the description of the study samples and the model used by the study to analyze the data.

Sample Size

In this study, the total sample size was determined based on Dillman (2011), using the formula:

$$S = \frac{NP(1-P)}{(B/C)^2\ (N-1)\ +\ P(1-P)}$$

where:

S = required sample size.

N = the population size = 769,960.

P = the population proportion expected to answer in a particular way (the most conservative proportion is .50).

B = the degree of accuracy expressed as a proportion (.05).

C = the Z statistic value based on the confidence level (in this case 1.96 was chosen for the 95% confidence level).

Therefore, the sample size can be determined as:

$$S = \frac{(769,960 \times 0.5)(1-0.5)}{(0.05/1.96)^2(769,960-1) + (0.5)(1-0.5)}$$
$$= \frac{192490}{501.067 + 0.25} = 384$$

However, for the purpose of data collection for this study, 750 questionnaires were distributed instead of the pre-determined sample number of 384 samples based on the cluster area sampling method to avoid the problem of the non response rate. According to Watson (2001), since it is not every selected sample that will likely respond, there is a need for the researcher to increase the sample size to avoid non response bias. Watson (1998) argued that at least a 50 percent rate of response is necessary for reporting and analysis. Finally 548 filled questionnaires were returned (which is more than 70% of the total number of the issued questionnaires) out of which nine questionnaires were discarded.

Sampling Technique

The sampling technique used in this study was multi-stage cluster sampling. In the first stage, the whole of the study area was divided into three groups (clusters) based on the geo-political zonal categorization of the study area; Bauchi south, Bauchi central and Bauchi north. In the second stage, two clusters (Bauchi south and Bauchi north) were selected randomly out of the three clusters. In the third stage, these two clusters were further categorized into two sub clusters of urban and rural areas. Then, 10 wards were randomly selected from the urban areas while 13 wards were selected randomly from the rural areas providing 23 selected wards for sampling. In the fourth stage, six communities were selected randomly from each of the selected wards of urban areas which made a total of 60 communities from the urban areas. On the other hand, another six communities were randomly selected from the selected wards of the rural areas making a total of 78 communities used from the rural areas. Thus, overall 138 sampled communities were used in the study. In the last stage, six households were systematically selected from each of the selected communities of the urban areas making a total of 360 households selected from the urban areas. On the other hand, 5 households were selected systematically from each of the selected communities of the rural areas making a total of 390 households selected from the rural areas. Finally, 540 questionnaires were analyzed.

Specification of the Model for Testing the Relative Income Hypothesis

Verme (2013) presented a standard econometric model for testing the RIH:

$$U = \beta_1 \ln(x_i) + \beta_2 \ln(r_i) + \delta Z_i$$

The dependent variable can either be categorical or continuous depending on the model to estimate. Empirically the modified multinomial logit model version of this model estimated in this research can be expressed as:

$$Y_{ij} = \beta_0 + \beta_1 INC_i + \beta_2 r_i + \beta_3 r_i LOC_i$$

where: Y_{ij} = main source of energy with the categories: firewood, kerosene, electricity, gas, traditional lighting sources, and semi electric source of lighting.

INC = income for household i, r = neighboring main source of fuel.

rLOC = is the interaction of r and location.

Results and Discussions

The main objective of this study was to test the relevance of the RIH on household energy choice and consumption. The two dimensions of household energy choice (cooking fuel and lighting fuel consumption choices) were tested separately.

Relative Income Hypothesis and the Household Cooking Fuel Choice

The validity of the relative income hypothesis was tested in relation to household cooking fuel choice. To conduct such a test, the study used two approaches: statistical and econometric. The statistical tests consisted of testing the relevance of the variable representing the relative income hypothesis in the previous estimated multinomial logit models (results not reported). The econometric method involved estimating a modified model of testing the relative income hypothesis proposed by Verme (2013). The results of the tests are discussed below.

Statistical Tests of Relative Income Hypothesis and the Household Cooking Fuel Choice

We conducted various statistical tests of the RIH in relation to the households' source of cooking fuel choice and the results of the tests are explained.

Test of the Variable 'Neighborhood Source of Cooking Fuel' (NCFUEL)

Here, from our earlier estimated model of household cooking fuel choice (result not reported), a likelihood ratio test of the variable representing neighborhood cooking fuel was conducted. The procedure involved first estimating the full model and calling it an unrestricted model. Then we removed the variable representing the relative income hypothesis and re-estimated the model again (the second model is known as the restricted model). We conducted the likelihood ratio test of the hypothesis:

H_0: the restricted and unrestricted models are non nested models. The result of the test is shown in Table 1:

Table 1 indicates the result of a specific variable test 'NCFUEL' in our estimated multinomial logit model (the estimated result, not reported). The result showed that the LR chi-square statistic is significant at .1 percent. This implies that the variable NCFUEL is relevant in explaining household cooking fuel source choice.

Fit Statistics of the Model

Similarly, the post estimation test of fit statistic was used to further ascertain the relevance of the theory of the RIH in explaining the household cooking fuel consumption pattern. The procedure followed in conducting this test was that first, the full model was estimated based on a multinomial logit model (the estimated MNL model was not reported due to space limits) and saved using the fitstat STATA command. Then, the partial model was estimated by removing the variable 'NCFUEL'. Then, the fit statistics of these models were established in order to see which of these two estimated models had a better fit to the data. The results obtained from the fit statistics are shown in Table 2.

Table 2 indicates the various fit statistics of the two estimated models. The saved model is the full model containing all the variables together with the variable 'NCFUEL', while the current model contains all the variables (as in the full model) except the variable 'NCFUEL' which is the focus of our analysis. The results showed that all three test statistics (the LR (D), AIC, and BIC) established that the full model (saved model) had a better fit than the partial (current) model. This was further evidence that the RIH can be used to explain the household cooking fuel consumption pattern.

Table 1
Likelihood-ratio test of a specific variable (NCFUEL)

LR	21.88
Prob > χ^2	0.0001

(Assumption: restricted nested in unrestricted model)
Source: Authors (2016)

Table 2
Test of model fit

	Current	Saved	Difference
Model	MNLM1	MNLM2	
D	550.425 (428)	528.546 (421)	21.879 (7)
AIC	630.425	616.546	13.879
BIC	19.771	17.658	2.113

Note: MNLM = multinomial logit model
Source: Authors (2016)

Wald Test of Individual Variable (NCFUEL)

This was the third statistical method followed to re-examine the validity or relevance of relative income hypothesis in explaining household cooking fuel choice behavior. The results of the Wald test are shown in Table 3.

Table 3 shows the result of the Wald test for the variable 'NCFUEL' which is one of the explanatory variables in the estimated model. Based on the result of the test, we reject the null hypothesis of non relevance and conclude that the variable is strongly relevant (significant at .1%) in the model. Econometric Approach of Testing the Relevance of Relative Income Hypothesis and the Household Cooking Fuel Choice (Verme model).

Econometric Approach of Testing the Relevance of Relative Income Hypothesis and the Household Cooking Fuel Choice (Verme Model)

In this case, various estimations were conducted to ascertain the validity of the RIH based on the model (modified version) of testing the RIH as proposed by Verme (2013). The Verme model was applied to see the relationship between household cooking fuel choice and the variables representing the theory of relative income hypothesis. The estimated model is shown in Table 4.

Furthermore, the estimated marginal effects of the model are shown in Table 5.

Tables 4 and 5; show the various coefficients and the marginal effects of the estimated model for testing the relationship between the relative income hypothesis and the household cooking fuel choice. The probability of the model shows that the overall fit of the estimated model is statistically significant at .1 percent level. From the estimated results, variables representing the theory of the RIH were statistically significant mostly at the 1 percent and 5 percent levels. Furthermore, all the variables had signs that conform to *a priori* expectations. For instance, the coefficient of income has a positive relationship with kerosene adoption, a 1 percent increase in income leads to an increase in the multinomial log-odd of adopting kerosene by about 0.39 units compared to biomass fuel. Similarly, a 1 percent rise in income, increases the multinomial log-odd

Table 3
T-test of NCFUEL

LR χ^2 (3)	20.06
Prob > χ^2	0.0002

Note: H_0 [0]o.ncfuel = [1]ncfuel = [2]ncfuel = [3] ncfuel = 0
Source: Authors (2016)

Table 4
Estimated model of relative income hypothesis and household cooking fuel choice

VARIABLE	(Kerosene)	(Electricity)	(Gas)
	1	2	3
Lincome	0.393***	0.634**	0.971***
	(0.142)	(0.300)	(0.262)
Location*Neighbourcookingfuel	1.713***	0.682	1.434**
	(0.332)	(0.603)	(0.683)
Neighbourcookingfuel	−2.337***	−0.829	−2.919***
	(0.347)	(0.704)	(0.649)
Constant	−1.663***	−5.023***	−4.754***
	(0.529)	(0.992)	(1.015)

Note: The reference category is firewood. Robust standard errors in parentheses, Pseudo $R^2 = 0.12$. ***$p < .01$, **$p < .05$, *$p < .1$ Wald $chi^2(9) = 76.04$, Prob > $chi^2 = 0.0000$
Source: Authors (2016)

of adopting electricity by about 0.63 units compared to biomass fuel when other variables are held constant. Furthermore, a 1 percent increase in income leads to an increase in the multinomial log-odd of adopting gas compared to biomass fuel by about 0.97 units. Additionally, the marginal effects of this variable indicate that a 1 percent increase in income decreases the probability of adopting biomass fuel as the main source of cooking fuel by about 9.5 percent, while it increases the probabilities of adopting kerosene, electricity or gas by about 4.9 percent, 1.6 percent, and 3.1 percent, respectively.

Furthermore, the result indicates that the coefficients of the neighboring source of cooking fuel and location interaction are statistically significant at 1 percent and 5 percent. Households that live in urban areas and who have the same main source of cooking fuel with their neighbors, have a higher multinomial log-odd of adopting kerosene compared to biomass fuel than otherwise by about 1.7 units. Similarly, the multinomial log-odd of adopting gas as the main source of cooking fuel compared to biomass fuel for households that live in urban areas and adopt the main cooking fuel source similar to their neighbors is higher than otherwise by about 1.43 units, when the remaining variables are held constant. The results shows that the interaction between living in urban areas and adopting a main source of cooking fuel similar to that of immediate neighbor reduces the household probability of adopting biomass fuel as the main source of cooking fuel by about 31.6 percent, while it increases the probability of adopting kerosene by about 27 percent. This implies that the location where the household lives and the type of cooking fuel mostly adopted in the community have a joint significant effect on the type of cooking fuel to be adopted and used.

Lastly, the variable 'NCFUEL' was found to be significant at the 1 percent level. Based on the estimated coefficient of this variable, the multinomial log-odd of adopting kerosene compared to biomass fuel is lower by about 2.3 units when the neighboring households adopt a similar main source of cooking fuel. Also the multinomial log-odd of adopting gas compared to biomass fuel is less by about 2.9 units when the neighboring households adopt a similar main source of cooking fuel. Similarly, the estimated marginal effects of this variable were significant at the 1 percent and 5 percent respectively. The results show that the probability of adopting firewood is higher by about 49.4 percent when the neighboring household adopts a similar source of main cooking fuel. In contrast, the probability of adopting kerosene as the main source of cooking fuel is lower by about 36.8 percent and for adopting gas by 12.7 percent when the neighboring households adopts a similar source of cooking fuel because most of the households have adopted a biomass fuel (such as firewood) in the study area and this explains why this variable increases the probability of biomass fuel adoption and reduces the probability of adopting another source of cooking fuel. All these findings support the relevance of the RIH for household cooking fuel choice and consumption. Also, it is in line with previous studies' (Khan, 2014; Kosicki, 1987; McBride, 2001; Torgler et al., 2006) validation of the application of the relative income hypothesis in other aspects (non energy consumption) of household consumption.

Relative Income Hypothesis and the Household Lighting Fuel Choice

Here, the validity of the theory of the RIH was tested in relation to the household lighting main fuel choice. In order

Table 5
Marginal effects of the estimated model of relative income hypothesis and household cooking fuel choice

VARIABLE	(Firewood)	(Kerosene)	(Electricity)	(Gas)
	0	1	2	3
Lincome	−0.0951***	0.0488**	0.0156*	0.0307***
	(0.0244)	(0.0211)	(0.00833)	(0.00910)
Location*Neighbourcookingfuel	−0.316***	0.270***	0.00631	0.0390
	(0.0554)	(0.0549)	(0.0176)	(0.0287)
Neighbourcookingfuel	0.494***	−0.368***	0.00154	−0.127**
	(0.0578)	(0.0665)	(0.0184)	(0.0495)

Note: Standard errors in parentheses ***$p < .01$, **$p < .05$, *$p < .1$
Source: Authors (2016)

to conduct such a test, the study used two approaches as in the section of household cooking fuel choice and the RIH. The results of the findings are discussed below:

Statistical Tests of Relative Income Hypothesis and the Household Lighting Fuel Choice

Here we conducted various statistical tests of the RIH in relation to the households' source of lighting fuel choice and consumption based on the previous estimated multinomial logit model of household lighting fuel choice (the estimated result is not shown due to space limitation). The results of the tests are explained below:

Test of a Variable 'Neighborhood Source of Lighting Fuel' (NLFUEL)

Here, from the earlier estimated model of household lighting fuel choice, a likelihood ratio test of the variable representing neighborhood lighting fuel was conducted. The procedure involved first estimating the full model and calling it the unrestricted model. Then we removed the variable representing the RIH and re-estimated the model (the second model was known as the restricted model). We conducted the likelihood ratio test of the hypothesis: H_0: the restricted and unrestricted models are non nested models.

The results of the test are shown in Table 6.

Table 6 indicates the results of a specific variable test for NLFUEL in our estimated multinomial logit model of household lighting fuel choice (estimated result, not reported). The results showed that the LR χ^2 statistic is significant at the 1 percent level. This implies that the variable NLFUEL is relevant in explaining the household lighting fuel source choice and that the relative income hypothesis is relevant in explaining the pattern of households lighting fuel choice.

Fit Statistics of the Model

Similarly, the post estimation test of the fit statistic was used to further ascertain the relevance of the theory of the RIH in explaining the household lighting fuel consumption pattern. The procedure followed in conducting this test was that first, the full model was estimated based on the multinomial logit model and saved using the fitstat command. Then, the partial model was estimated by removing the variable 'NLFUEL'. After that, the fit statistics of these models were established in order to see which of these two estimated models had a better fit to the data. The results obtained from the fit statistics are shown in Table 7.

Table 7, shows the various fit statistics of the two estimated multinomial logit models of household lighting fuel choice. The saved column shows the various test statistics for the full model. The full model contains all the variables including the variable 'NLFUEL,' while the column titled 'current' shows the test statistics of the partial model. This model contains all the variables (as in the full model) except the variable 'NLFUEL' which is the focus of analysis. The results show that both the LR (D) and the AIC establish that the full model (saved model) has a better fit than the partial (current) model. This is further evidence that the relative income hypothesis can be used to explain households lighting fuel choice behavior.

Table 6
Likelihood-ratio test of a specific variable (NLFUEL)

LR χ^2 (2)	13.22
Prob > χ^2	0.0013

(Assumption: restricted nested in unrestricted)
Source: Authors (2016)

Table 7
Test of model fit

	Current	Saved	Difference
Model	MNLM1	MNLM2	
D	615.999 (408)	602.781 (384)	13.219 (6)
AIC	681.999	674.781	7.219
BIC	49.035	49.988	−0.953

Note: MNLM = multinomial logit model
Source: Authors (2016)

Wald Test of Individual Variable (NLFUEL)

This is the third statistical method conducted to reexamine the validity and relevance of the RIH in explaining household lighting fuel choice behavior. The results of the Wald t-test are shown in Table 8.

Table 8 shows the result of the Wald test for the variable 'NLFUEL' which is one of the explanatory variables in the estimated multinomial logit model of household cooking fuel choice source. Based on this result, we reject the null hypothesis of non relevance and conclude that the variable is strongly and significantly (1%) relevant in the model. This is a further validation of the RIH in describing household lighting fuel consumption behavior.

Econometric Approach of Testing the Relevance of Relative Income Hypothesis and the Household Lighting Fuel Choice

Here, the test of the RIH in relation to household lighting fuel choice was conducted by estimating the modified Verme model. The results of the estimated model are shown in Table 9.

Table 8
Wald test of NLFUEL

LR χ^2 (3)	11.78
Prob > χ^2	0.0028

H_0 [0]o.ncfuel = [1]ncfuel = [2]ncfuel = 0

Table 9
Coefficients of the estimated modified Verme model for testing relative income hypothesis (lighting fuel choice)

VARIABLE	(Semi-electricity)	(Traditional)
	1	2
Lincome	−0.430***	−0.382*
	(0.146)	(0.196)
Location* Neighbourlightingfuel	−0.102	−1.094***
	(0.243)	(0.366)
Neighbourlightingfuel	−1.061***	−0.494
	(0.302)	(0.398)
Constant	1.390**	0.270
	(0.572)	(0.818)

Note: Robust standard errors in parentheses ***$p < .01$, **$p < .05$, *$p < .1$.
The omitted category (reference) is electricity
Source: Authors (2016)

Furthermore, the marginal effects of the estimated model are shown in Table 10.

Tables 9 and 10 contain the estimated model for testing the RIH in relation to household lighting fuel choice. The overall model is statistically significant at the .1 percent level. The estimated model consists of variables representing the relative income hypothesis that were regressed on the type of lighting fuel source to be chosen by the households based on the estimated Verme model. The lighting fuel source has three categories: electric, semi-electric, and traditional sources of lighting. The traditional source includes the use of firewood and traditional/kerosene lamps. Semi-electricity includes rechargeable lanterns, battery lanterns, and torch lights. The base category is electricity used as a lighting source. The results indicate that all the variables are statistically significant mostly at the 1 percent level. Based on the estimated coefficient of the household income, a 1 percent rise in income of the household head reduces the multinomial log-odd of adopting semi-electric lighting source compared to electricity by about 0.43 units. Also, it reduces the multinomial log-odd of adopting traditional source of lighting compared to electricity by about 0.38 units when the other variables are held constant. Additionally, the estimated marginal effects of this variable indicate that a 1 percent increase in the income of the household head increases the probability of adopting electricity as the main source of lighting by about 9.2 percent, while reducing the probability of adopting semi-electric sources of lighting by about 6.9 percent. This is in line with the RIH that predicts that the income of households also has a significant impact on the pattern of their consumption behavior.

Furthermore, the coefficient of the interaction variable between households adopting a similar source of lighting as their neighbors and the location of the household indicates that households that are living in urban areas and also that adopt a similar main source of lighting as their neighbors have lower multinomial log-odds of adopting a traditional source of lighting by about 1.094 units compared to electricity than the other types of households. Moreover, the estimated marginal effects of this interactive variable indicated that the probability of adopting electricity as the main source of lighting fuel for households that are living in urban areas of Bauchi State and who also have a similar main source of lighting as their immediate neighbors is higher by about 8.38 percent compared to other households. Also, their probability of adopting a traditional source of lighting is lower by about 8.94 percent than other households. This is in line with *a priori* expectations and also supports the RIH that the interaction of the environment and the immediate neighbors of households have a significant impact in shaping the consumption pattern of the households.

Lastly, the estimated model has shown that the variable representing the similarity of the type of lighting fuel source adopted by the household to that of its immediate neighbor is significant and therefore relevant to the analysis of household energy choice. The results have shown that the multinomial log-odd of adopting a semi-electric lighting source compared to electricity is lower by about 1.061 units when the household adopts a similar (electricity) lighting fuel to that of its immediate neighbor. Similarly, the estimated marginal effects showed that the probability of adopting electricity as the main source of lighting fuel is higher by about 21.8 percent when the household and its immediate neighbor have adopted a similar source of lighting fuel compared to others. Moreover, the probability of adopting a semi-electric source of lighting is lower by about 20.7 percent when the household and its immediate neighbor have adopted the same source of lighting because the most widely used source of lighting is electricity and that is why the probability of adopting electricity increases, while for other sources it decreases, which is in line with the RIH that the consumption pattern of households is influenced by the consumption behavior of their immediate neighbors. Also, it is in line with the validation in previous studies (Khan, 2014; Kosicki, 1987; McBride, 2001; Torgler et al., 2006) of the application of the RIH in other aspects (non energy consumption) of household consumption.

Table 10
Marginal effects of the estimated modified Verme model for testing the relative income hypothesis (lighting fuel choice)

VARIABLE	(Electricity)	(Semi-electricity)	(Traditional)
	0	1	2
Lincome	0.0923***	−0.0691***	−0.0232
	(0.0280)	(0.0254)	(0.0161)
Loc* Neighbourlightingfuel	0.0838*	0.00560	−0.0894***
	(0.0468)	(0.0429)	(0.0275)
Neighbourlightingfuel	0.218***	−0.207***	−0.0117
	(0.0664)	(0.0665)	(0.0349)

Note: Standard errors in parentheses ***$p < .01$, **$p < .05$, *$p < .1$
Source: Authors (2016)

Conclusions and Policy Recommendations

The main aim of this study was to test the relevance of the axiom of the relative income hypothesis (RIH) in explaining household energy choice and consumption. The study has contributed to the existing literature on testing the RIH by establishing a relationship between the axiom of the relative income hypothesis and household energy consumption. Several tests of this relationship were conducted using both statistical and the econometric methods. The results of the various statistical tests (Wald t test, likelihood ratio test and fit statistics) have shown that the RIH is relevant to the pattern of household fuel choice. Moreover, the estimated modified Verme model for testing the RIH has shown that all the variables (income, neighborhood main source of energy and the interaction between environment and the neighboring main source of energy) which together represent the RIH were statistically significant in all the estimated models and therefore, the RIH is relevant in explaining household energy use (for both cooking and lighting fuel choice, respectively) especially in developing countries.

Since an increase in income was found to have a significant impact on discouraging household adoption of biomass fuel as the main source of cooking fuel and also on discouraging the adoption of a traditional source of lighting, policies and programs aimed at raising income earnings of individuals should be embarked upon to discourage the adoption of biomass fuel and other traditional sources of lighting. Income can be increased via employment generation, wealth creation, increasing government expenditure, empowering small and medium scale industries, and skills development.

A strong and well-implemented program that will introduce many households to a modern energy source for cooking and lighting should be emphasized because when some households are introduced to modern household energy appliances, other households will soon possess the same, since the pattern of energy use of immediate neighbor has a significant impact on the type of fuel source to be adopted by households.

However, this study was limited by the fact that it was static in nature, that is, the study cannot provide explanation on the validity of the relative income hypothesis in relation to household energy choice and consumption over time.

Conflicts of interest

None.

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