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Determinants of energy poverty in South Africa[1]

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Abstract

This paper provides empirical evidence on the determinants of energy poverty in South African households using the National Income Dynamics Survey (NIDS, 2012), while controlling for individual, household and demographic characteristics. This is formulated within a logistic regression framework, while defining energy poverty using the expenditure approach consistent with the definition by the Department of Energy (DoE) of South Africa. The model reveals that household expenditure patterns, race, education level, household and dwelling size, location of the household and access to electricity are important factors in explaining the state of energy in South African households. This paper also discusses limitations in defining energy poverty using the expenditure approach. Finally, some recommendations are made for regulators and policy makers.

Keywords: energy, energy poverty, Logit, South Africa

1. Introduction

South African policies echo the sentiment for energy access through the White Energy Paper (RSA, 1998) where it is stated that, "energy security for low-income households can help reduce poverty, increase livelihoods and improve living standards" (RSA, 1998). Access to energy is important as it leads to an eradication of poverty through improved education, health services and may eliminate structural unemployment (Department of Energy, 2009).

The South African government believes that energy poverty deepens general poverty and contributes to an erosion of health and education outcomes (RSA, 1998). As a result of it being a policy focus, the country has made strides in addressing energy poverty. This is evidenced in the Medium Term Strategic Framework (MTSF, 2009), which states that the government aims to, "include, amongst others, diversification of the energy mix in pursuit of renewable energy alternatives and the promotion of energy efficiency".

According to the Integrated Energy Plan (IEP) (2013), South Africa has an urban electrification rate that is around 80% and rural electrification rates that is around 50%. Eskom is South Africa's electricity public utility provider and in terms of electrical supply is the dominant player; supplying 92.8% of the country's electricity demands. The remaining 7.2% is supplied by Independent Power Producers (IPP) from renewable energy sources.

Even though South Africa possesses large electrification rates, Ferriel (2010) states that in total there are approximately 2.5 million rural and urban households in the country not connected to the national electricity grid, in addition to the millions that are connected to the grid but are not able to pay for electricity. As a result, even with a high electrification rate, households earning low incomes cannot afford sufficient electricity to improve their welfare (Mapako and Pasad, 2005). Many South

African households predominantly use traditional and unclean energy resources for many activities such as cooking, lighting and drying of farm produce (*Statistics SA*, 2008). The attainment of the Millennium Development Goals (MDGs) rests on the availability and access of affordable energy to all people (Kohler, Rhodes and Vermaak, 2009). Kohler, Rhodes and Vermaak, (2009) believe that in order to achieve the MDGs, policy needs to be developed to encourage the use of efficient energy at the household level, so that the use of unclean energy such as biomass and charcoal is minimised.

The following section provides a literature review, which explains the meaning of energy access and energy poverty. It ends with an overview of some of the policy initiatives the South African government has implemented in order to combat energy access and energy poverty issues.

2. Literature review

2.1 Energy access

There is a lack of consensus in the literature on what the term "energy access" means. One of the reasons is that there have been problems in the techniques and concepts used to define it (Kohler *et al.*, 2009). For example, definitions that have been based on minimum physical levels of cooking or heating are often location specific due to the difference in climatic conditions between different parts of the world (Barnes *et al.,* 2011).

The IEA, in its World Energy Outlook (2009), identified three levels of access to energy services depending on household energy needs and the benefits energy services provide. These include:

1. The minimum level of energy access required by households to satisfy basic human needs (electricity for lighting, health, education and community services).
2. The energy access required by households to improve productivity (electricity and modern fuels to improve productivity)
3. The level of energy access required by households to satisfy modern society needs (modern services for domestic appliances, increased requirements for cooking and heating and private transportation)

Kohler, Rhodes and Vermaak, (2009) describe a theory of transition in which households gradually ascend an "energy ladder. The ladder, beginning with traditional biomass fuels (firewood and charcoal), moves through to transition fuels (kerosene, coal and charcoal) and then on to modern commercial fuels (Liquefied Petroleum Gas (LPG), natural gas, or electricity) as incomes rise and urbanisation grows (Kohler *et al*., 2009). According to Leach (1992), during periods of economic growth it is expected that people living within a community will switch from using traditional fuels to more modern fuels such as electricity, due to the industrialization and urbanisation that takes place. This is the energy transition prevalent in the model and states that as a country develops economically, households will convert to more efficient sources of energy.

Hosier and Dowd (1987) conducted empirical research in order to determine which factors have a significant effect on the energy ladder and factors which cause movements up the ladder focusing on people's choice of household cooking fuels in Zimbabwe. They found that the choice of fuels was determined by household income, regional ecological potential, relative fuel prices, household size, and the perceived fuel wood accessibility. The results showed that a larger household size would cause a transition from wood to kerosene, but decreases the chances that electricity will be used over kerosene or wood. Hosier and Dowd (1987) also found that households located in urban areas were significantly more likely to use kerosene than wood. When relative per unit price of kerosene was high compared to the per unit price of electricity, this increased the probability of a household choosing electricity over kerosene. Furthermore, households that did not perceive wood as being difficult to collect, preferred wood. The results also showed that substitutions to more sophisticated energy sources, was likely to occur when household income rises.

Leach (1992) also investigated the energy transition model. At the time, it was found that in the poorest developing countries biomass accounted for 60-95% of total energy consumption. In urban areas of these countries energy transitions progressed slowly and even slower in rural areas. For example in India, urban transitions were quicker when there was a rise in relative firewood prices and an increase in household income. As a result, the use of biomass for cooking and heating fell from 42% to 27% (Leach, 1992). These energy transitions were driven by the social economic changes that give households the opportunity to use modern fuels.

Leach (1992) also found that the price of these fuels is a major barrier in the transition to more modern fuel sources especially in developing countries where the price variations are greater. A household's ability in obtaining modern fuels is another significant constraint on the energy transition model. This was observed from the patterns of household energy use in comparison to the settlement size and the distance from major trading centres and roads in rural areas located in India (Leach, 1992). In these locations, even the highest income households only used biofuel, with maybe kerosene for lighting. This was the case because more efficient fuels could not easily be accessed in small and remote settlements due to the insufficient supply of modern fuels in their settlements, as a result of poor distribution (Leach, 1992).

The same sentiments are echoed in the South African context. Even though an increase in income dictates a higher demand for energy, the transition to more modern energy is not easy for many South African households. This is evidenced in empirical work done by the Energy Sector Management Assistance Programme (ESMAP, 2000), the International Economic Agency (IEA, 2002) and Heltberg (2004), including research on energy use patterns in South Africa by Aitken (2007), who all reveal that many South African households rely on multiple energy sources for their energy needs and this applies to both electrified and non-electrified households.

Kohler, Rhodes and Vermaak, (2009) highlight that access to efficient and affordable cooking and heating fuels, like LPG or kerosene, are vital to alleviating the effects of energy poverty. This finding provides a strong empirical challenge to prevailing energy transition theories and the "energy ladder model. Kohler *et al*., (2009) explain several possible explanations for this. One is that unreliable supplies require households to rely on diverse sources of energy. Another is that different energy sources are more cost-effective in some uses than in others. For instance, it may make economic sense to use electricity for lighting but LPG for cooking. Therefore, the focus on income is only one part of the problem.

2.2 Energy poverty: Measurement

Broadly defined, energy poverty is viewed as the *lack of access to modern energy services,* be it electricity, heating or cooking fuels, necessary for human development (Kohler, Rhodes and Vermaak, 2009). Several authors have been able to theoretically provide a definition for energy poverty but practically fail to agree on a threshold poverty line. There are numerous approaches that are used to measure energy poverty. Each will be discussed in turn:

- *The income approach:* is defined based on the share of a household's income that is spent acquiring basic energy sources (Fahmy, 2011). This approach shows that for the lowest income households, the share of income spent acquiring fuels is usually higher than those of higher income households.
- *The self-reported approach:* is based on a household's perception of adequate amount of household fuels and their expenditures (Fahmy, 2011).
- *The objective approach:* Objective approach is usually operated by the government, it is measured by calculating the proportion of household's income that needs to be spent on energy. The government can deem a household energy poor if more than 10% of its income is sent on energy (Waddams *et al.,* 2007) or the government can rely on expert assessments that link people's thermal needs and physical characteristics such as weather temperature and climate (Fahmy, 2011).
- *The access-adjusted approaches:* The access-adjusted measure looks at the accessibility of an energy source by households in specific areas Kohler *et al*., (2009).
- *The expenditure approach:* The expenditure approach is considered to be the universal measure of energy poverty and has been adopted by a number of countries because of its attractiveness. The approach doesn't require governments to identify the amount of energy that is being used by households, and the average energy source used by households can be easily be determined at the expenditure poverty line that can be based on household energy surveys (Barnes, Shahidur and Hussain, 2010). Households with energy expenditures above this threshold are considered energy poor and are likely to be confronted with difficult choices between meeting energy requirements and spending on competing goods. This poverty expenditure line is generally estimated to be 10-15% of income.

The expenditure approach has been adopted as the measure of energy poverty in South Africa (DoE, 2013). This is the equivalent of a middle income household earning R10 000 a month and spending up to R1 000-R1 500 a month on acquiring energy services (Aitken, 2007).

Kohler *et al*., (2009) compared the results of an expenditure approach and access-adjusted approach based on South African households. Using a 2008/2009 DoE survey amongst LSM1-LSM3 in all nine provinces for electrified and non-electrified households, indices of energy poverty were created. The energy burden of households was calculated using energy expenditure as a percentage of total income. The access-adjusted measure was calculated using the percentages of households below different poverty lines (667kWh, 1200kWh and 2000kWh) by province (Kohler *et al*., 2009).

The results showed that access-adjusted data was more robust and informative (Kohler *et al.*, 2009). For example, the expenditure approach showed that Northern Cape's energy burden was 11.8% for electrified households, and 11.6% for non-electrified households. For Limpopo, the energy burden was 11.7% for the electrified and 16% for non-electrified households. On the other hand, the access-adjusted approach showed that more than 60% of non-electrified households in the Northern Cape and Limpopo were below the

667kWh energy poverty line, meaning they had access to 667kWh or less per person per year. Using the expenditure approach these provinces were considerably not energy poor, but when the type of fuels used is considered using access-adjusted approach these areas were considerably energy poor.

The United Kingdom government defines energy poverty using the objective method and a study by Fahmy (2011) provides a summary of benefits relating to the objective approach. Households that are defined as being energy poor must spend more than 10% of their income on all fuel that is used to warm their homes to a decent level. The energy poverty measure focuses on warmth because 25 000 people die every winter as a result of cold homes (Hope, 2013). Fahmy (2011) iterates that the advantage of using the objective approach as opposed to the expenditure approach is that it has the ability to identify households that are spending below the energy poverty line due to under-consumption. As well as being able to estimate the proportion of households that will need to spend disproportionately in order to maintain the adequate temperatures in their homes, these households may be supported by the government (Fahmy, 2011). Compared to the self-reported approach, the objective approach is not subjected to the measurement error that may result due to changes in wording (Fahmy, 2011). This is because changing the wording when conducting subjective surveys is known to change people's answers (Tietenberg and Lewis, 2012).

The approaches mentioned above each have advantages and disadvantages when measuring energy poverty. It is unlikely that one approach is able address all the concerns. The measure chosen should be based on the policy objectives that are trying to be achieved (Fahmy, 2011).

2.3 Policy initiatives in South Africa

Currently, Eskom and the Department of Energy (DoE) are embarking upon endeavours to increase the electricity supply by commissioning renewable energy from IPPs. The policy implemented to achieve the commissioning of renewable energy from IPPs is the Renewable Energy Independent Power Producer Procurement Programme (REI4P). The South African government has made massive strides to ensure that there is sufficient supply to meet the growing demand of electricity. This will see the price of electricity increase for South African households connected to the national grid. Furthermore, policy benefits will accrue only to households connected to the national grid who can afford to pay for the energy supply. This does very little for households which are not connected to the grid.

In July 2003, the government endorsed the Free Basic Electricity (FBE) policy as a possible solution the country's electrification challenges. According to Mvondo (2010), The FBE policy was derived from the government decision that was made two years prior to provide basic services to poor households, with a priority put on water, energy and sanitation services (DoE, 2013). The policy compels municipalities and state owned firms that are in the electricity sector, to supply a certain amount of electricity to poor households in the country for free. Households that are already connected to the grid qualify for 50 kWh every month, as this is considered sufficient to satisfy basic energy needs. Off-grid households are given a R40 subsidy per month that is paid towards a R58 monthly service fee which makes for up to an 80% subsidy, such that these households only have to make payments of R18 a month (DoE, 2013).

Based on a study that was done in Buffalo City in the Eastern Cape using a Quality of Life (QoL) survey, Mvondo (2010) found that the FBE policy had a major social impact on its population. It was found that the FBE policy was very limited in the productive use of electricity as only 34% of the households were able to run at least one electricity dependent business (Mvondo, 2010). Regarding the health benefits, it was found that 92% of the households indicated that they had not experienced any illness cases in the last 9 months, the study also indicated that the electricity usage patterns were related to better health practices (Mvondo, 2010). For example, fires that were caused by using candles were reduced with better access to electricity. Regarding education, it was found that electricity access had a positive effect on the time children spent studying in most households, despite this positive impact some households complained that children would spend more time watching television (Mvondo, 2010).

Ferriel (2010) conducted a qualitative study based on 30 households to see if the 50kWh on the FBE was sufficient. Households were asked the following two questions: 1) is the 50kWh of FBE sufficient? And 2) what amount of free electricity is reasonable? The results showed that only 25% felt that the 50kWh was sufficient but this had to be used with other energy sources. It also illustrated that on average households used up to 750kWk per month. This means that the free allocation was only 6.6% of monthly electricity use.

Ferriel (2010) concluded that the objective of the policy marginally improves the lives of the poor, removing the health risks of using wood for cooking. However, given that the 50kWh amount still requires many households to use other energy sources, it cannot improve people's lives especially for those living in urban areas. The FBE policy also states that homes applying for FBE need to be fitted with a pre-paid meter, and then vouchers have to be used in order to access the free based allowance (Mvondo, 2010). This further creates inequality as the poor are often unable to buy vouchers due to the uncertainty of incomes in poor households. The policy also states that electricity demand for poor households could be met by restricting the current supply to 20 amps (Ferriel, 2010). This limited 20 Amp restriction creates an inconvenience to low income as it limits the number of domestic tasks they are to perform. Mvondo (2010) also recommended that social education programmes should be implemented together with FBE in order to restrict the negative social effects of having electricity.

In 2008, the DoE implemented an Incline Block Tariff (IBT). IBTs divide the electricity price into several steps or blocks. The first block of electricity is at the lowest price. As the customer purchases more electricity during the month, the electricity bought will eventually fall in block two, which is a bit more expensive. This process repeats automatically as the customer purchases further electricity to move into block 2. At the end of the month, the history is reset and the customer will again start the next month from block 1. The process to move from the one block to the next is automatic and depends only on the amount of electricity that is acquired by the customer. The movement to the next block is not at all affected whether the purchases are spread over many transactions or if all the electricity is part of one transaction. Because the blocks increase in the price, customers can save money by not buying more electricity than what they will use during the month. It is much better to wait until the next month and start to buy again at the low price (DoE, 2013).

This paper seeks to add to the energy poverty literature and build and extend on the work by Ismail (2015) by empirically measuring energy poverty as defined by the DoE. More importantly, this paper empirically tests for determinants associated with energy poverty amongst households. This is discussed in detail in the sections that follow. Therefore, the main goals of the paper are as follows (Ismail, 2015):

1. Estimating energy poverty of households using the expenditure approach as defined by the Department of Energy of South Africa (DoE).
2. Constructing a logistic (logit) regression model of the determinants of energy poverty using the measure of energy poverty developed in 1) as a dependent variable.

The data is drawn from the National Income Dynamics Survey (2012) since it provides detailed information of income and expenditures of households, as well as individual, household and demographic characteristics of South African households.

The paper is organised as follows: Section 3 describes the data used, including a description of variables used in estimation. Section 4 presents the measurement of energy poverty and the methodology for logistic regression analysis. Section 5 presents the results of the estimation and tests to ensure the predictive power of the model. Section 6 talks about the limitations of the energy poverty measurement in estimation. Section 7 provides policy recommendations for regulators and policy makers. Lastly, section 8 concludes.

3. Data

The National Income Dynamic Survey (NIDS, wave 3, 2012) is used for estimation in the logit regression analysis. The NIDS dataset is by nature an individual dataset and each individual is tracked with a unique identification number across each of the three waves. There are various questionnaires that consist of the NIDS data: including an individual, child, proxy and household questionnaire. Each household is tracked with a household identification number. This is unique within a wave, but not unique across the three waves. For this reason, household transitions in and out of energy poverty can be tracked at a particular point in time. However, it is difficult to track over time. Therefore, analysis of individuals is done at the household level using only wave 3. Each questionnaire is structured and given to the individual in the household to be used for the collection of information. The household questionnaire is typically answered by the oldest female in the household. The questionnaire has a set of questions on variables such as gender, marital status, household size, dwelling size, location of the household, education, and energy use, and income and expenditure patterns of the household, amongst others (NIDS, 2012).

This paper only focuses on relevant information from individuals in households needed to conduct this study. It follows the empirical work done by Dunga, Grobler and Tchereni, (2013) and builds and extends on the work by Ismail (2015) to estimate energy poverty and its determinants among South African households. First, energy poverty is calculated for each of the individuals in the households using the expenditure approach. This allows us to determine the number of individuals in households below the expenditure energy poverty line within the sample (households spending more than 10% of their income on energy sources). Second, a discrete choice analysis using a logistic model is adopted to analyse determinants of energy poverty. Below are some statistics which describe the dataset used in the analysis.

3.1 Descriptive statistics

The sample used for estimation is comprised 6 961 households and 29 918 individuals. Table 1 shows that of the individuals in the sample, close to 25% live in energy poverty as defined by the expenditure approach. Figure 1 shows the relationship between Energy poverty and income. Where income represents imputed household income after tax split into deciles. It is clear to see that the poorest 20% of individuals are also the most energy poor in the sample. Therefore, as income increases, individuals face lower energy poverty.

Table 1: Individuals in sample
Source: NIDS, 2012

Energy poverty dummy variable	*Frequency*	*Percentage*
Energy well-off	22,349	74.7
Energy poor	7,569	25.3
Total	29,918	100

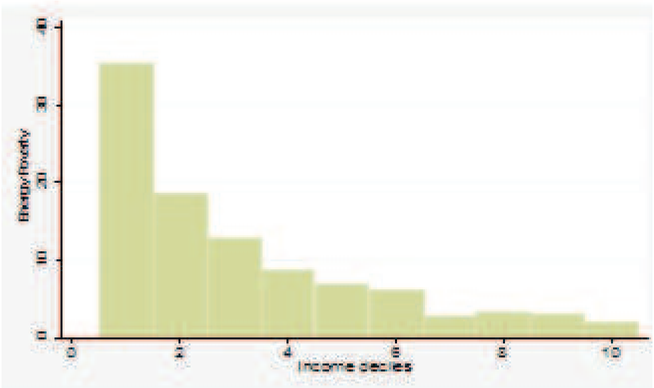

Figure 1: The relationship between energy poverty and income

Table 2 gives a list of all the variables used in the logistic regression analysis.

Table 2: Variables used in the logistic regression analysis
Source: NIDS (201)2

Variable	*Frequency*	*%*
Individual characteristics		
Gender		
Male	13,453	44.97
Female	16,465	55.03
Race		
African*	25,014	83.61
Coloured	3,855	12.89
Asian/Indian	326	1.09
White	723	2.42
Educational attainment		
Tertiary education	1,957	6.54
Completed Matric	2,949	9.68
Incomplete schooling	24,737	82.68
Variable	*Frequency*	*%*
Household characteristics		
Electrified	24957	83
Location		
Rural	16,529	55.25
Urban	13,389	44.75
Married	5,273	17.62
Household size		
1	945	3.16
2	2162	7.23
3	3390	11.33
4	4096	13.69
5	4475	14.96
6	3828	12.79
7	3122	10.44
8	2256	7.54
9	1827	6.11
10	1150	3.84
>10	2667	8.92
Number of people in the household		
1	1771	5.92
2	3987	13.33
3	5126	17.13
4	6386	21.35
5	4040	13.5
6	3201	10.7
7	2127	7.11
8	1508	5.04
9	778	2.6
10	442	1.48
>10	514	3.19
Demographic characteristics		
Province of the household		
Gauteng	2537	8.48
Limpopo	3099	10.36
KwaZulu Natal	9175	30.67
Eastern Cape	3773	12.61
Northern Cape	2133	7.13
North West	1933	6.46
Western Cape	3212	10.74
Mpumalanga	2310	7.72
Free State	1746	5.84
Sample size	29918	

* African refers to Black South Africans

4. Methodology

Logistic regression

The logistic regression model is used in estimation. This model makes use of predictors to estimate probabilities that an event does or does not occur relying on similar inferential statistical methods as in Ordinary Least Squares (OLS) (Gujarati, 2004). Theoretically, a decision maker n faces J alternatives. The utility that the household obtains from alternative j can be represented as:

$$U_{nj} = V_{nj} + \varepsilon_{nj} \quad (1)$$

Where, U_{nj} is total utility; V_{nj} and ε_{nj} represents unknown variables classified as stochastic utility (Gujarati, 2004). The logistic function is obtained by assuming that each ε_{nj} is an independently, identically distributed extreme value. The density for each unobserved component of utility is (Gujarati, 2004):

$$f(\varepsilon_{nj}) = e^{-\varepsilon_{nj}} e^{-e^{-\varepsilon_{nj}}} \quad (2)$$

And the cumulative distribution is given by (Gujarati, 2004):

$$F(\varepsilon_{nj}) = e^{-e^{-\varepsilon_{nj}}} \quad (3)$$

From the above, this represents the probability that decision maker chooses. Therefore, the empirical model is formulated as follows:

f(Energy poverty) =
(exptpt, expfood, expsch, gender, race, educ, location, electrification, hhsize, dwelsize, marital, ε) (4)

Dependent variable

In expenditure terms, a household is considered to be energy poor if 10 percent or more of its income is on energy (Fahmy, 2011; Department of Energy, 2009). This definition therefore requires data on energy expenditure at the household level and total income.

The NIDS (2012) data set provides information of monthly expenditure patterns of electricity as well as other energy sources. It also provides information of a household's monthly income. Therefore, a summation of all energy expenditure was taken as a proportion of household after tax imputed income as follows:

$$\text{Energy budget share of total household budget} = \frac{\text{expenditure on all energy sources}}{\text{After tax income}} \times 100 \quad (5)$$

Households whose energy expenditure budget exceeded 10 percent were regarded as being energy poor and therefore they were coded 1 and those who were spending less than 10 percent on energy received a code of 0 (zero). This allows for the creation of a dummy variable for energy poverty in this manner as shown in Table 1.

5. Results

Expenditure patterns

In general, a household will consume goods and services which will maximise its utility of consumption, thereby making the most of limited resources to maximise utility. As consumers are insatiable and utility functions grow with quantity, the only thing that limits a household's consumption of a good is its budget. Furthermore, consumers cannot obtain an additional unit of one good without giving up some other goods. Following this logic:

The results in Table 3 show that there is a positive and statistically significant relationship between energy poverty and transport expenditure as well as energy poverty. The results suggest that the odds ratio of 0.105 is in favour of transport expenditure to increase the energy poverty level. In terms of elasticity as reported in Table 3, the relationship between transport expenditure and energy poverty is inelastic. This means that if the price of energy increases, the household cannot forgo transport expenditure and must cushion the price increase of energy from elsewhere in its budget. More specifically, a 1 percentage increase in transport expenditure could increase energy poverty by 0.13 percent.

There is also a positive and statistically significant relationship between energy poverty and schooling expenditure at the 1% level. The odds ratio of 0.009 was in favour of schooling expenditure to increase the energy poverty level. Like transport expenditure, the relationship between schooling expenditure and energy poverty is inelastic. A 1 percentage increase in electricity expenditure could increase energy poverty by 0.015 percent.

There is a statistically negative relationship between food expenditure and energy poverty. At the 1 percent level of significance, the odds ratio predicts that households who spend more on food are likely to have better energy access. As Table 3 shows, for every 1 percentage point increase in the food budget, there is likely to be a 0.034 percentage decrease in energy poverty. Said differently, low energy poverty levels are likely to be associated with higher expenditures in food for members of a household as funds are released from spending on energy and the gains are moved towards improved consumption of food.

Gender

There is a positive relationship between gender and energy poverty although the association was statistically insignificant to reject the null hypothesis. The odds ratio however, shows that one is more likely to be energy poor if they are female than male. This finding opposes Dunga, Grobler and Tchereni, (2013), who find that males are more likely to be

Table 3:
Source: NIDS (2012)

Energy poverty variable	*Odds Ratio*	*Elasticity*	*Std. Error*
Socio-economic characteristics			
Expenditure on transport	0.105‡	0.130	(0.006)
Expenditure on schooling	0.009‡	0.015	(0.003)
Expenditure on food	-0.003‡	-0.034	(0.001)
Individual characteristics			
Gender	0.030	0.065	(0.036)
Race			
Coloured	-0.138†	-0.908	(0.081)
Asian/Indian	2.390‡	0.007	(0.155)
White	1.642‡	0.209	(0.134)
Educational attainment			
Tertiary education	-0.254*	-0.034	(0.530)
Completed Matric	-0.300	-0.038	(0.596)
Incomplete schooling	0.153	0.179	(0.224)
Household characteristics			
Electrified	0.296†	0.224	(0.117)
Location	-0.409†	-0.096	(0.179)
Married	-0.140	-0.029	(0.191)
Dwelling size	-0.141‡	-0.783	(0.058)
Household size	0.277‡	1.289	(0.058)
Demographic characteristics			
Province of the household			
Gauteng	-0.197	-0.032	(0.094)
Limpopo	-0.679	-0.085	(0.365)
KwaZulu Natal	0.437	0.064	(0.308)
Eastern Cape	0.676‡	0.044	(0.090)
Northern Cape	1.269‡	0.082	(0.304)
North West	0.592	0.036	(0.349)
Western Cape	(Omitted)	(Omitted)	(Omitted)
Mpumalanga	0.827	0.056	(0.369)
Free State	0.600	0.048	(0.104)
Constant	0.615†	0.096	(0.670)
N	29918		
Log-Likelihood	-10246.265		
Significance: * 10%, † 5%, ‡ 1%			

energy poor in rural Malawian households. The reason is that men culturally do not go to the forest to fetch firewood the way women do in parts of Africa.

However, with regards to the South African context, this result is consistent with authors such as Annecke (2002). She explains that the positions which women hold along the energy chain reveal a clustering around the biomass sector and women are seldom in control of resources. Therefore, they have greater access to inefficient sources which lead to them being energy poor.

Race

In 2008, nearly 80 percent of the population was of African descent, while the Coloured and White population accounted for 9 percent each. The remaining 2 percent of the population were of Asian or Indian origins. Even though Africans make up the highest percentage of the population, the distribution of resources is extremely unequal across these groups. For example, white people report about 8 times the average per capita income and expenditure levels of Africans (Gradin, 2011). This indicates a stark inequality between the races.

The results in Table 3 highlight this, as African people are more energy poor than white and Asian/Indian people. These results are significant at the 1% level. It was also found that Coloured people are more likely to be in energy poverty compared to African people. This was found to be significant at the 5% level. Differences of poverty between races can be explained by unequal access to education, family planning, or the labour market, or by the fact that they live in more deprived areas (Gradin, 2011). Each of these factors is likely to affect the income of an individual and contribute towards higher energy poverty.

Educational attainment

At the 10% level, education of the members of the household was statistically significant if they had a tertiary level education. It was also found that possession of a matric certificate also reduced energy poverty. However, this finding is statistically insignificant. There is a negative relationship between level of education and energy poverty. This is expected, since higher education levels are associated with higher income levels and therefore the energy share in the expenditure budget should be smaller. The odds ratio obtained in the regression output, supports this finding. Furthermore, it shows that an individual's completion of tertiary education reduces energy poverty by 0.034 percent. The findings also indicate that having incomplete schooling increases energy poverty. Even though this finding is not significant, it highlights the importance of a complete education for increased income and acts as a strong determinant of energy poverty.

Based on a study in a rural area in Assam, India, Kanagawa and Nakata (2008) investigated the relationship between energy access and the improving socio-economic conditions affecting rural areas in developing countries. They found education to be the most essential component for poverty reduction. Kanagawa and Nakata (2008) explain that poor households are not able to complete their secondary schooling because financial constraints do not allow them to pay the needed educational expenditures. Education therefore affects energy poverty as low education rates hamper people's household incomes as a result aren't able to afford modern energy services causing energy poverty.

Marital status

On marital status, the relationship was negative suggesting that homes with married couples or committed partners were less likely to be energy poor than those who were not. The reason for this could be that married couples combine their income and share the expenses of the household, including energy expenditure. However, this relationship is not significant.

Household and dwelling size

The higher the number of people residing in the household, the higher the incidence of energy poverty. The odds were that it was more likely for a household with more members to be energy poor than those with less members. This could be because as the number of household members increase, a fixed household budget must be distributed amongst more people – thus, increasing energy poverty. This relationship is statistically significant at the 1% level.

There was a negative relationship between the size of the dwelling unit and energy poverty. This relationship is statistically significant at the 1% level. The negative relationship suggests that individuals dwelling in larger houses were less likely to be energy poor compared to those living in smaller units. One reason to explain this, is that the larger your income, the larger your household, therefore one has more access to more modern energy sources Ismail (2015).

Demographic characteristics

In terms of the demographic characteristics, the Western Cape was dropped in the regression due to collinearity with the other variables in the regression. All provinces exhibited a positive relationship with energy poverty, except for Gauteng and Limpopo. This means that households situated in these provinces are more likely to be energy poor. However, of these four provinces, only the Eastern Cape and the Northern Cape displayed statistical significance at the 1% level. Kohler, Rhodes and Vermaak, (2009) found that the Eastern Cape is one of the provinces with the lowest electrification rates in South Africa. Furthermore, this could also signal structural issues inherent within these provinces with regard to energy access.

Gauteng and Limpopo exhibit a negative relationship with energy poverty. This means that households situated in these provinces are less likely to be energy poor. However, only Gauteng province is statistically significant at the 5% level. Of all the provinces, Gauteng is the most urbanized and this could mean that inhabitants have more access to cleaner and cheaper energy sources.

The results also show that households who are electrified are more likely to be energy poor than households who are not. This is significant at the 5% level. This is an interesting result, as access to electricity does not necessarily mean one will be less energy poor. This reflects the unaffordability of electricity as lower income households cannot necessarily afford electricity provided by the national grid, even though they might have access to it.

Lastly, there is a location dummy, which indicates that households situated in rural areas in South Africa are more likely to be energy poor than houses situated in urban areas. This could mean firstly that, households in urban areas have access to better jobs and therefore higher incomes, such that they can afford energy. Second, rural households are slower in transitioning up the energy ladder and have access to less efficient energy sources that cost more than cleaner energy.

5.1 Evaluation of the energy poverty regression model

Logistic analysis relies on other statistics to analyse the reliability of any model (Gujarati, 2004). The Log-Likelihood Ratio test is distributed as a Chi-Square and is computed to test the overall performance of the model (Gujarati, 2004). The Chi-Square statistic was 2332.84 and it was statistically significant. Thus, the null hypothesis that the overall explanatory power of the model could not be relied upon was rejected. The predictors in the logistic regression were collectively important in explaining the behaviour of energy poverty in South African households.

The Pseudo R-squared was 62 percent implying that the model explained about 62 percent of the deviations in the probability of energy poverty.

A further goodness of fit test that is recommended for logistic regressions in the literature is the Hosmer-Lomeshow (HL) Chi-square statistic (Ping, Lee & Ingersoll, 2002; Gujarati, 2004). The statistic is distributed as a Pearson Chi-square and is evaluated through a log-likelihood estimation calculated from a 2 x g table of observed and expected frequencies, where g is the number of groups formed from expected probabilities of each one of the observations (Gujarati, 2004). This test was conducted based on the results in Table 3 and the null hypothesis that the model was a good fit to explain the deviations in the behaviour of energy poverty is accepted even at the 10 percent level of significance. The value of the HL statistic was 32.1 with the probability to accept the null hypothesis of about 91 percent.

6. Limitations when defining energy poverty

The measure of energy poverty based solely on household expenditures can be problematic because poor households in countries such as South Africa typically rely on cheap but inferior biomass for their energy needs. As a result, estimating energy poverty in the way above can underestimate the extent of energy poverty in households (Kohler, Rhodes and Vermaak, 2009).

Kohler, Rhodes and Vermaak, (2009) put forward the following example: If households X and Y both spend 15% of their income on energy, then the way in which the expenditure approach is defined above will classify both households as being equally poor. However, they explain that if the type of energy used is taken into account: If it was found that X uses paraffin and candles, while Y uses electricity, then Y obtains a better use of quantity which is more useful since electricity is a more efficient energy source. Therefore, X must be classified as poorer than Y, by taking into account the quantity of energy used by the household, rather than just its cost. Furthermore, if household X now gains access to free basic electricity (FBE), it should be classified as less poor than it was before but its poverty status would not change if energy poverty is defined according to the expenditure approach.

The reader should note that even though this study is consistent with the DoE's interpretation of energy poverty, more efficient results can be achieved if quantity of electricity is taken into account in household expenditure/income data as well as information on FBE at the household level. Neither the General Household Survey (GHS) nor the NIDS data as used in this study allow for this information to be incorporated. This then leads to recommendations in the following section.

7. Recommendations

The policy recommendations are based on the results found in section 5. Households can be made less poor by simply making all energy cheaper if one solely looks at the expenditure approach. However, more rigorous analysis must be done by dissecting energy sources that South Africans rely on. With regard to the analysis done in this paper, this could not be done across each of the waves in the NIDS dataset as households do not have unique identification numbers across the three waves. Therefore, the expenditure approach becomes more attractive as it allows measurability of energy poverty.

With regards to electrified households, the National Energy Regulator of South Africa (NERSA) and the DoE can play an important role in the determination of prices that individuals face, for the following reason:

As highlighted by Ismail, Mabuza, Xolo and Pillay (2014): Allowable Revenue (AR) of a state owned enterprise such as such as Eskom hugely influences the amount of revenue the entity is entitled to receive as determined by the regulator (NERSA). The tariff decision of NERSA is normally based on the amount of revenue that would reasonably be required to recover a set of costs included in the regulated asset base (RAB) amongst others (AER, 2011).

$$\text{Allowable revenue (AR)} = (\text{RAB} \times \text{WACC}) + D + E + +C + F \quad (6)$$

$$\text{Tariff} = \text{Allowable revenue/ Quantity of output sold by the regulated entity} \quad (7)$$

Where: The RAB is the cumulative historical investment made by the utility. The weighted average cost of capital (WACC) reflects the opportunity cost of the investments made by the investor. D = depreciation of the RAB over time. E = operational expenses incurred by companies. C = claw back and F= F-Factor, which is additional revenue to meet debt obligations that may be granted by a Regulator. If the allowable revenue excluding the F-factor does not enable the applicant's regulated activity to operate with a debt service cover ratio acceptable to its financiers, then additional revenue may be allowed (Ismail *et al*., 2014).

The RAB is typically the largest component of AR and it grows by the amount of the net capital expenditure outlays made by Eskom (Meaney and Hope, 2012). One reason why companies increase capital outlays is to expand infrastructure capacity as the demand for services increase (AER, 2011). Therefore if capital expenditure increases, RAB increases; so does the AR and subsequently the tariff. Regulators must ensure that capital outlays allowed into the RAB must be prudently acquired. If they are not acquired prudently, it will unnecessarily inflate the RAB. Ismail *et al*., (2014) highlight that if there are any imprudent costs in the RAB, this will be passed through to consumers. Therefore, NERSA plays a crucial role in evaluating prudent pricing of Eskom and therefore, the protection of consumers. As such, any increase in tariff increase applications by Eskom must be scrutinised so that consumers face the most efficient prices.

Also related to pricing is a study done by Thopil and Pouris (2013) showed 'actual sales and revenue' figures of Eskom over the 2012/13 period. The study indicated that two sectors - industrial and mining (the largest two sectors in South Africa) - contributed 77% of the sales but generate only 67% of the revenue, with the industrial sector showing the largest disparity. This trend can be better observed in the revenue to sales ratio of the percentage contribution, shown in Table 4.

Table 4: Revenue-to-sales ratio of electricity in South Africa, per sector
Source: Thopil and Pouris (2013)

Sector	*Revenue: Sales ratio*
Residential	1.56
Commercial	1.13
Industrial	0.82
Mining	0.96
Agriculture	1.75
Traction	1.5

The largest reverse parity (where revenue is greater than sales) occurs in the agricultural sector, which is a vital sector of the South African social make-up. More importantly for this study, is that the residential sector also shows a degree of reverse parity. This finding suggests that the industrial sector, in spite of being the largest sector in terms of sales, is under-priced[1] (Thopil and Pouris, 2013).

This leads to the question, why does Eskom increase prices equally in the residential and industrial sectors, when the benefits that these sectors receive are not proportional? Is it the best approach to equally increase the prices among all sectors or is a discriminatory pricing approach across sectors more beneficial for both the economy and Eskom (Thopil and Pouris, 2013)? Therefore, a primary recommendation is for the DoE in collaboration with NERSA, to look into differential pricing across sectors. This might alleviate energy poverty amongst households (Ismail, 2015).

Given many of the poorest households are located in remote rural areas, expansion of the electricity grid may be prohibitively expensive. As shown in Table 3, accessibility to the grid will not solve energy poverty. The FBE policy must be relooked at, as Feriel (2010) showed that the policy only marginally improves the lives of the poor, given that the 50kWh amount still requires many households to use other energy sources and it cannot improve people's lives.

Kohler, Rhodes and Vermaak (2009) also suggest that further research should be done into the cost-effectiveness of small-scale renewable energy projects and that any type of renewable energy expansion be accompanied by an education programme, so that households do not view alternative energy sources as being inferior to electricity (Ismail, 2015).

The final recommendation regards the problems associated with estimating energy poverty using the expenditures approach. The DoE should use a more efficient approach in defining energy poverty, as there are many limitations defining energy poverty in this way. It is recommended that future rounds of the household expenditure surveys such as the GHS and NIDS data sets should collect information on the prices per kWh that households pay for their individual energy sources, in addition to the total cost (Ismail, 2015). This will enable researchers to calculate more accurately the quantity of energy used, and thus to identify more precisely the degree of energy poverty experienced by households (Ismail, 2015).

8. Conclusion

This paper used the NIDS wave 3 (2012) dataset to achieve two main objectives. First, it estimated the energy poverty line using the expenditure approach for South African Households. Second, it estimated the determinants of energy poverty of these households by means of a logistic regression model. It was found that when these households increase their expenditure on transport and schooling, it significantly increases energy poverty since more of a household's budget is allocated away from energy spending. Food expenditure has the opposite effect. If individuals within the household possessed education at the tertiary level, it significantly decreases energy poverty since education increases income. African people are more likely to be energy poor than White and Asian/ Indian people, but not significantly more than Coloured people. This highlights stark inequality between the different races. This paper also finds that larger households were significantly less likely to be energy poor but households with more inhabitants within it are more likely to be energy poor.

Households who were connected to the national electrical grid were found to be more energy poor. This is an interesting finding as it highlights the fact that connectivity is only one part of the problem. Affordability of basic services is an issue that needs to be addressed. Households situated in rural areas were found to be more energy poor than households in urban areas. Lastly, it seems that the provinces with the highest significant energy poverty rates are the Northern Cape and the Eastern Cape.

This paper acknowledges the limitations of estimating energy poverty using the expenditure approach as it does not incorporate energy efficiency or FBE. This paper was unable to incorporate these elements because of unavailability of data at the household level within the NIDS (2012) data set. Therefore, this paper ends with recommendations to government as well as regulators. Regulators and government agencies should ensure electricity is efficiently priced and also look into differential pricing across sectors. Current policies such as the FBE policy must be revised, such that it contributes towards more intensive energy poverty eradication. Furthermore, accessibility and affordability of efficient energy sources such as electricity should be made available to all South Africans. This is an expensive notion – therefore, this paper suggests that education campaigns around renewable energy options must be made available to poorer households. Further, the DoE should use a more efficient approach in defining energy poverty. Lastly, in order for a more accurate estimation of energy poverty using household data sets should incorporate data on pricing and quantity of different energy sources and information on free basic electricity, so that more accurate results can be obtained in the future.

Notes

1. This paper builds and extends on the work done by Ismail, Z. (2015). An Empirical Estimation of Energy Poverty in Poor South African Households. *Journal of Economics and Sustainable Development,* Vol. 6 No. 13, 2015.
2. One of the primary reasons for standing contractual agreements between Eskom and large industrial users such as mines. These contracts are equally beneficial for both entities: large industrial users contribute to the largest section of revenue for the utility while being able to keep their utility costs low

References

Australian Energy Regulator (AER) (2011). How are the Electricity Prices set in Australia.

Aitken, R. (2007). Household Energy Use: a comparison of household energy consumption and expenditure across three provinces. Journal of Energy in Southern Africa, 18(1).

Annecke, W. (2002). The rich get richer and the poor get renewables: the WSSD, energy and women, a malevolent perspective. Agenda: Empowering Women for Gender Equity. 52:8-16.

Barnes, Douglas F., Shahidur R. Khandker, and Hussain A. Samad., (2011). Energy poverty in rural Bangladesh. Energy Policy. 39(2): 894-904.

Department of Energy (2009). Socio-Economic Impact of Electrification: Household Perspective 2009.

Department of Energy. (2013). A Survey of Energy Related Behaviour and Perceptions in South Africa. [Online] Department of Energy. Available: http://www.energy.gov.za/files/media/Pub/DoE-2013-Survey-of-EnergyRelated-Behaviour-and-Perception-in-SA.pdf [Accessed 15 May 2014].

Department of Energy (DoE) (2013). Integrated Resource Plan for Electricity (IRP) 2010-2030. Update Report 2013. Pretoria: Department of Energy.

Department of Minerals and Energy (2001). Guidelines to the National Electrification Planning.

Dunga, S. H. Grobler, W. and Tchereni, B. H. M. (2013). Economic Analysis of Energy Poverty in South Lunzu, Malawi. Journal of Economics and Sustainable Development. Vol. 4, No. 2013.

ESMAP. (2000). Energy and Development Report 2000 - Energy Services for the World's Poor. The World Bank. GSSD (2006), Gauteng Strategy for Sustainable Development: State of Play Report [Online].

Fahmy, E. (2011). The definition and measurement of fuel poverty. A briefing paper to inform consumer focus's submission to the Hills fuel poverty review, University of Bristol.

Ferriel, A. (2010). Free basic electricity. A better life for all. Johannesburg: Earthlife Africa.

Gradin, C. (2011). Race, poverty, and deprivation in South Africa. Society for the Study of Economic Inequality. Working paper series ENCINEQ WP 2011-24.

Gujarati, D. N. (2004). Basic Econometrics, 4th Edition. Mac Gaw-Hill, London.

Heltberg, R. (2003). Household Fuel and Energy Use in Developing Countries – A Multi-country Study. The World Bank.

Hosier, R. and Dowd, J. (1987). Household fuel choice in Zimbabwe: an empirical test of the energy ladder hypothesis. Resources and Energy. 9 (4): 347-361.

International Energy Agency (IEA) (2009). World

Energy Outlook, 2009
International Energy Agency (IEA) (2002). World Energy Outlook, 2002.
Ismail, Z. (2015). An Empirical Estimation of Energy Poverty in Poor South African Households. Journal of Economics and Sustainable Development. Vol. 6, No. 13, 2015.
Ismail, Z., Mabuza, P., Pillay, K., and Xolo, S. (2014). Infrastructure development within a regulated environment: concerns for regulators. Journal of Economic and Financial Sciences. 7(S):569-586.
Kanagawa, M. and Nakata, T. (2008). Assessment of access to electricity and the socio-economic impacts in rural areas of developing countries. Energy Policy. 36 (6): 2016-2029.
Kohler, M., Rhodes, B. and Vermaak, C. (2009). Developing an Energy-Based Poverty Line for South Africa. Journal of Interdisciplinary Economics.
Leach, G. (1992). The energy transition. Energy Policy. 20(2): 116-123.
Mapako, M. and Prasad, G. (2005). The Free Basic Electricity (FBE) policy and rural grid connected households, solar home system (SHS) users and unelectrified households. Domestic Use of Energy conference, March 2005. Cape Town: Cape Technikon.
Meaney, A. and Hope, P. (2012). Alternative ways of financing infrastructure investment. Potential for “novel” financing models. Discussion paper No. 2012-7, Oxford, UK: Oxford Consulting.
Mvondo, J. (2010). Impact of access to free basic electricity on household’s poverty in Buffalo City Municipality in the Eastern Cape. Unpublished PhD diss. Fort Hare: Department of Economics, University of Fort Hare.
Pachauri, S. & Spreng, D. (2003). Energy Use and Energy Access in Relation to Poverty. CEPE Working Paper No. 25 (June 2003), pp 1-13.
Pachauri, S., Mueller, A., Kemmler, A. and Spreng, D. (2004). On measuring energy poverty in Indian households. World Development, 32(12): 2083-2104.
Ping, C. J., Lee, K. L., & Ingersoll, G. M. (2002). An introduction to logistic regression analysis and reporting. The Journal of Educational Research, 96(1).
Republic of South Africa (RSA), (1998). White Paper on the Energy Policy of the Republic of South Africa. Department of Minerals and Energy. December 1998.
Statistics South Africa. (2008). General Household Survey 2008.
The Presidency RSA. (2009). Medium Term Strategic Plan: 2009-2014.
Thopil G.A. & Pouris A. (2013). International positioning of South African electricity prices and commodity differentiated pricing. S Afr J Sci. 2013; 109(7/8), Art #0075, 4 pages. http://dx,doi.org/10.1590/sajs.2013/20120075.
Tietenberg, T. and Lewis, l. (2012). Environmental Economics and Policy (6e). Boston, United States of America: Addison-Wesley.
Waddams, C., Brazier, K., Pham, K., Mathieu, L. and Wang, W. (2007). Identifying fuel poverty using objective and subjective measures. Centre for Competition Policy. 7(11).

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