Determinants of household electricity consumption in South Africa

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Abstract

Little is known about residential electricity demand in developing countries. In order to shed some light on this topic, this study combines data from South Africa's recent Income and Expenditure Survey with data from the National Energy Regulator of South Africa to estimate the determinants of residential energy demand. Combining electricity tariff data from the regulator with expenditure survey data from households provides an opportunity to explore the determinants of the demand for electricity. Due to the large number of zeroes in the dataset, a two-part model is employed. The results indicate that household income and electricity price are major demand determinants, and for the full two-part model, electricity demand is normal, as well as downward sloping, although inelastic in both cases; as expected, substitute fuel use impacts these elasticities. We also find that access to free basic electricity, a policy designed to improve access to electricity does what is expected. It is associated with increases in the probability that households purchase electricity and reduces total expenditure on electricity. Household demand is also higher for appliance-rich households in urban areas, especially if there are more household members and they live in larger dwellings.

Keywords: Electricity; Household; Two-part model; South Africa

JEL classification: Q41, Q48

1. Introduction

With increasing economic development, energy consumption in South Africa has risen. This rise has been driven by two separate components. Firstly, following the end of apartheid, the government committed to electrification. Dinkelman (2011) notes that at least two million households (close to one-quarter of the total) were connected to the grid by 2001, which was much faster than the roll-out achievements by the US under President Roosevelt's Rural Electrification Act. Thus, more people had access to electricity than before, and, as underscored by Dinkelman (2011), the roll-out could be tied to the economic development achievements in the country. Secondly, South Africa's economic output relies heavily on primary industries (Kohler, 2014), such as mining, which are energy intensive, and, although output in those sectors has been cyclical, it has generally increased over the last decade in order to fuel

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development in China. These two features, along with the fact that investment in new generation capacity dropped to zero between 2002 and 2006 (Bayliss, 2008), led to a severe energy crisis in 2008 (Bayliss, 2008; Gaunt, 2008).

To mitigate that energy crisis, Eskom, the state utility, planned in 2005 to expand its generation capacity by 17 120 MW (megawatts).[1] However, such expansion does not come online quickly. Thus, in addition to expansions in supply, a variety of energy efficiency and demand side management (EEDSM) activities were put in place, many focused on the residential sector, to reduce both peak demand and overall electricity consumption. Although research is underway to examine the effectiveness of these interventions, a spate of rolling blackouts in January and February of 2015 suggest that these strategies have not been entirely effective. Possibly, effectiveness could be improved, if the strategies were targeted more carefully, which requires a better understanding of the end-users. In this research, we focus on one electricity end-user, the residential sector, and we examine the determinants of electricity usage in an effort to highlight potential avenues for intervention to potentially curb residential sector electricity consumption.

Compared to other sectors, energy consumption patterns in the residential sector are more complicated. Households are decentralised decision-making units, and come in all shapes and sizes. Energy consumption patterns differ from one household to another, potentially affected by economic, socio-demographic, geographic and physical characteristics. Furthermore, uncertainties associated with human behaviour naturally pose challenges, when considering programmes and policies that might be implemented in the residential sector.[2] Thus, household electricity usage behaviour will depend on income and the price of electricity, as well as a number of other factors, such as substitute energy sources. In many African countries a number of households make use of firewood, paraffin and charcoal, and these energy sources affect electricity consumption and vice versa; see Heltberg (2004), Louw et al. (2008) and Johnson and Bryden (2012) for analysis on relationships between electricity and substitute energy sources of firewood, paraffin and charcoal. Brounen et al. (2012) indicate that residential consumption varies with household income and family composition. Meanwhile, *lifestyle* could reflect social and behavioural patterns associated with appliance use (Sanquist et al., 2012), and, therefore, the stock of electric appliances is associated with increased electricity consumption (O'Doherty et al., 2008; McLoughlin et al., 2012; Bedir et al., 2013). Dwelling physical factors (i.e., building type, size, thermal and quality characteristics) are related to household energy consumption (Tso and Yau, 2003; Brounen et al., 2012). Regional differences also matter; Niu et al. (2012) find that high-income urban residents consume more electricity than low-income rural households, while other regional characteristics also matter (Hondroyiannis, 2004; Narayan and Smyth, 2005). With the exception of Niu et al. (2012) and Tso and Yau (2003), who consider China, the previously listed research is taken from developed countries.

It is clear from the preceding discussion that prices and income are not the only determinants of electricity usage.

[1]Eskom website: `http://www.eskom.co.za/OurCompany/CompanyInformation/Pages/Company_Information_1.aspx`. The expansion target is to be achieved with one pumped-storage and two coal-fired power stations, together with one wind farm and a concentrated solar-thermal station. However, the partial focus on coal-fired solutions has raised a number of concerns over pollution externalities (Nkambule and Blignaut, 2012; Riekert and Koch, 2012).

[2]In South Africa, electricity is the main energy source for household use (Stats SA, 2012a), while consuming about 25% of total energy in 2012 (DOE, 2016); this proportion has likely increased, due to further progress in the National Electrification Programme (Bekker et al., 2008), increased appliance affordability and increasingly wealthy households (even though appliances are becoming more efficient in their own right).

Therefore, we accessed tariff data from the National Energy Regulator of South Africa (NERSA) and merged it with the 2010/2011 South African Income and Expenditure Survey (SA IES, Stats SA, 2012b), which resulted in a database that is nationally representative and includes price variation, as well as other potential economic and socio-demographic determinants of electricity demand. We use this combined data to examine the standard features of demand, income and price effects, while controlling for additional factors in our effort to highlight potential avenues for intervention in the residential sector. The breadth of the SA IES questions, along with the approach taken to merge price data, offers an opportunity to analyse household electricity consumption, inclusive of many household-level variables.

We are not the first to use expenditure data, although most examples in the literature come from developed countries. For example, Barnes et al. (1981), Branch (1993) and Fell et al. (2014) use the U.S. Consumer Expenditure Survey from different periods to estimate price/income elasticities of demand for residential electricity, while Halvorsen and Larsen (2001) examine factors affecting growth in Norwegian household demand from 1976 to 1993 using that country's annual consumer expenditure survey. One developing country exception is Anderson (2004) who undertakes a similar analysis (combining SA IES data and regulator price data) in South Africa, focusing only on prepaid electricity users. That analysis, based on the year 2000 data, is in need of updating, partly to determine whether or not residential consumers became more price-conscious after the 2008 electricity crisis experience. We also extend that analysis, including additional types of electricity consumers, using a larger set of electric appliances and accounting for Free Basic Electricity (FBE, a program designed to improve access to electricity for low-income South Africans).[3]

Using the SA IES data, unfortunately, comes with additional issues. One advantage is the availability of household-level income, expenditure and demographic information; however, it rarely includes price information; thus, as noted, a secondary source of price variation is needed, which we access from NERSA, albeit at a regional level. Furthermore, expenditure data in a country like South Africa, where some households access FBE and some grid-connected households do not actually report using electricity, include a fair share of zero observations. Thus, for the analysis, a two-part model (2PM) is applied to take account of two separate features: the probability that a connected household actually reports electricity consumption and the consumption of electricity, conditional on purchase.

Although economic theory argues that consumer behaviour is affected at the margin, and, therefore, consumers should respond to marginal changes in the price, households receive their electricity bills *ex-post*, typically for at least one month of use;[4] thus, behavioural responses may be easier to measure with average prices (Fell et al., 2014; Ito, 2014). One measure of an average, and the one we incorporate is the area-level price. As noted by Branch (1993) and Halvorsen and Larsen (2001), who use municipal-level prices, doing so is synonymous to assuming that households in the same municipality face the same electricity price. On the other hand, Alberini and Filippini (2011)

[3]A number of households receive free basic electricity (FBE), described in Section 2, and may choose not to purchase beyond their free allotment. Finally, there is evidence that 0.9% of Eskom generated electricity is stolen at the residential level, and, therefore, usage may not be reported by households with access, but do not pay for their electricity (Source: `http://www.esi-africa.com/wp-content/uploads/2014/05/Maboe-Maphaka.pdf`).

[4]In South Africa, electricity meters are read only every other month in a number of municipalities to keep costs down, while electricity bills are "estimated" in a less than completely transparent fashion.

use the average prices of a given electric utility, instead of household-level price; their data are from the American Housing Survey. The South African situation is rather similar; due to local-level control over distribution, end-user prices are regional, and households in those regions face the same tariff structure. Fortunately, the SA IES includes appropriate information to match the household to their local-level electricity distributor, which allows us to assign them a regulator-approved tariff.

The South African literature on electricity consumption – see Table 1 – has, nearly exclusively, made use of time series data and generally ignored the residential sector. The available time series data are used to forecast residential (Ziramba, 2008), industrial (Inglesi-Lotz, 2014) or aggregated (Pouris, 1987; Amusa et al., 2009; Inglesi, 2010; Inglesi-Lotz and Blignaut, 2011) electricity demand in South Africa, although Inglesi-Lotz and Blignaut (2011) decompose South Africa's electricity consumption across non-residential sectors. Regardless of the sector considered, none of these time series studies are able to incorporate more detailed information about the end-users in that sector.

Table 1 about here

The exceptions to the time series focus are Louw et al. (2008), Anderson (2004), described earlier, and Jack and Smith (2015). Louw et al. (2008) examine factors affecting electricity usage decisions in low-income households from two typical rural villages in South Africa. The prices of substitute fuels (paraffin and candles) are included in their models; they find that substitute fuels impact low-income household electricity consumption, although cross-price elasticities are inelastic. Unfortunately, they neither include electricity price data in their final analysis nor uncover any price effects (Louw et al., 2008). Jack and Smith (2015) use customer transaction data from the City of Cape Town combined with property value records. They focus on prepaid electricity users, while examining the relationship between property value and electricity purchasing patterns. They find fewer monthly prepaid purchases, but greater total expenditure, for higher value properties, suggesting that prepaid electricity meters introduce flexibility, allowing liquidity constrained households to purchase electricity (Jack and Smith, 2015). By incorporating price information, more detailed household-level data, and accessing relatively recent data, our research is able to complement these studies. In particular, we examine the contribution of economic and socio-demographic factors to electricity demand in South Africa, while providing one of the first studies undertaken in a context marred by severe electricity supply concerns.

The results of the analysis are supportive of price and income inelasticity, as was expected. Our estimated income elasticity is 0.128, while the estimated price elasticity is -0.305. Furthermore, a number of socio-demographic, geographic and physical factors also influence household electricity consumption, as well as the estimated elasticities. These factors include various dimensions of wealth and potential energy need. The significant impacts of these determinants offer implications for energy policies. First of all, increasing the price may not be the most effective reduction strategy, due to inelastic demand. Second, it is necessary to consider other relevant factors, when designing energy efficiency programmes/policies. For example, energy efficiency programmes could be tailored for different population groups in different areas. In addition, energy efficiency improvement could be incorporated into poverty alleviation targets.

2. South African Residential Energy Consumption

South Africa (a newly industrialised country according to the World Bank) is energy-intensive, because its main industry, minerals extraction and processing, along with historically low energy prices, have likely provided little incentive to save energy. Eskom's average residential electricity tariff was ZAR 0.40/kWh (kWh: kilowatt hour; ZAR 0.40 ≈0.06 USD; USD 1=ZAR 6.35) in 2005/2006 (Newbery and Eberhard, 2008) and ZAR 0.606/kWh (≈0.08 USD; USD 1=ZAR 7.25) in 2010/2011 (Eskom, 2011), respectively. However, an electricity crisis in 2008 had a number of effects. An amount of R60 billion was allocated to support Eskom's capital financing requirements over the foreseeable future, and to support energy efficiency and increased renewable energy sourcing (National Treasury, 2008). The crisis also led Eskom to propose and NERSA to accept annual electricity tariff increases between 16% and 25% for households in South Africa (DOE, 2012b); the National Energy Efficiency Strategy argued that the low price of energy was a significant barrier to energy efficiency (DOE, 2012a). In addition, consumers began to understand that generation capacity in South Africa was constrained. DOE (2012b) survey evidence implies that a large proportion of households are aware of basic energy-saving methods; 75% of households are aware that switching off lights when leaving the house is energy saving, while half of the households claim to undertake this action. Furthermore, 40% of households are aware that switching off the geyser at certain times during the day or night results in energy savings, while 15% claim to take that action.

According to our survey data, approximately 71.5% of households consume electricity, but only 1.1% use gas (including gas supplied through either a public network or purchased in cylinders); 11.7% and 11.6% use liquid and solid fuels, respectively. The percentage of households that use electricity for cooking increased from 57.9% in 2002 to 73.1% in 2011 (Stats SA, 2012d). Possibly, the biggest efficiency problem relates to heating water, i.e, water heater/geyser inefficiency. Water-heating contributes 40%-50% of monthly electricity consumption in the residential sector (Meyer, 2000).

In an effort to alleviate constraints on electricity availability, a series of EEDSM projects have been promoted by the South African government and Eskom. For instance, a large-scale solar water heating rebate programme was initiated in 2009 to encourage households to switch to solar water heating.[5] In addition, a residential heat pump rebate programme was run from 2011 with a similar goal: reduce the load associated with residential water heating.[6] Furthermore, since lighting is a large energy user in households, a number of large-scale lighting retrofit projects aiming to reduce the residential lighting load have also been implemented in South Africa (Ye et al., 2013, 2014). De la Rue du Can et al. (2013) present evidence that the residential sector has delivered 76% (2 333 MW) of all peak demand savings. The improvement resulted mainly from mass roll-outs of compact fluorescent lamps (CFL); over 53 million incandescent bulbs were replaced with more efficient CFL bulbs.

[5] Department of Energy, http://www.energy.gov.za/files/swh_frame.html and Eskom: http://www.eskom.co.za/sites/idm/Residential/Pages/hotwatersolutions.aspx.

[6] Eskom, http://www.eskom.co.za/sites/IDM/Documents/specifications_for_heat_pumps_on_rebate_programme.pdf.

Despite these improvements, South Africa was back in electricity crisis mode in 2014. Rolling scheduled blackouts occurred from early November 2014 through mid February 2015.[7] This spate of power cuts was the worst since the 2008 crisis (`http://ewn.co.za/2014/12/08/Eskom-ceo-apologises-for-load-shedding`). Despite the electricity capacity expansion programme, launched in 2005, Medupi and Kusile, the initial coal-fired power plants in the plan, were many years behind schedule.[8] In the meantime, most of the power stations are approaching the end of their lifespan, resulting in substantial operational inefficiencies (De la Rue du Can et al., 2013).

Electricity generation capacity is and has been constrained in South Africa for a number of years, and, although there are programmes in place to try to reduce demand through improvements in energy efficiency, primarily within the residential sector, it is also true that electricity prices are going to rise over the next few years. Therefore, to provide additional information that could help in both policy formulation and in designing additional EEDSM programmes (or redesigning current ones), an improved understanding of the determinants of household electricity consumption is necessary.

Even though improving energy efficiency is an urgent need, South Africa's history also affects electricity demand. Too many poor households have no access to basic services, such as water, sanitation and electricity; a recent study (Harris et al., 2017) argues that changes in household electricity access are closely related to household formation and dissolution dynamics in South Africa. As part of the National Indigent Policy (DPLG, 2009), which aims at poverty alleviation, the FBE policy has been in place, since 2003 (DME, 2003). Although FBE is meant to cover the entire country, it is not implemented in the same way in every municipality. Behind the policy lies the desire to provide 50 kWh of electricity per month to poor households (DME, 2003). Figure 1 shows the proportion of consumer units receiving FBE services from municipalities and service providers over the period 2010 and 2011 (Stats SA, 2012c).[9] As can be seen in Figure 1, there are regional differences with respect to FBE provision between 2010 and 2011.

Figure 1 about here

A total of 870 GWh (Gigawatt hour) of FBE was consumed in the 2014/2015 financial year (NERSA, 2015). Given that total electricity consumption in South Africa is 204 163 GWh (Eskom, 2015), FBE consumes 0.4% of total electricity. Although only a small percentage of the total, FBE access (as seen in Figure 1) is high. However, the proportion of those receiving FBE dropped from 2010 to 2011, due to a change in the FBE access mechanisms; access became self-targeting, technical or geographical, rather than broad-based (Stats SA, 2012c). In other words, FBE is provided at different levels by different methods over time and space. According to Stats SA (2012c), more than 70% of municipalities provide FBE at the standard level – 50 kWh, while 8% supply FBE at other levels. A recent NERSA

[7] Load shedding can be traced to the collapse of a coal storage silo at the Majuba power station in Mpumalanga (`http://www.citypress.co.za/business/eskom-silo-collapse-unexpected-matona/`), while the breakdown of two Eskom generators made the condition worse (`http://www.bdlive.co.za/business/energy/2015/01/08/failures-take-eskom-to-load-shedding-brink`).

[8] Construction on Medupi power station started in May 2007 (Eskom, 2007). The first unit was scheduled to come into service early in 2011, and six units totalling 4 500 MW were to be online by 2015. Medupi produced its first power from the beginning of March 2015 (`http://www.fin24.com/Economy/Medupi-produces-its-first-power-20150302`). Kusile power station Unit 1 was scheduled for operation in early 2017 (Eskom, 2014), but has not yet produced any electricity.

[9] Figure 1 is not necessarily comparable with the SA IES data, because: (1) The data come from municipalities instead of households; (2) Most municipalities can not identify multiple households served by one billing unit or delivery point (hence, "consumer units" instead of "households" underpin the data); and (3) The reporting period is 1 July, 2010, to 30 June, 2011, which is different from the SA IES we use.

report (NERSA, 2015) indicates that in the 2014/2015 financial year, 88% of municipalities supply 50 kWh FBE; but 250 kWh, 150 kWh, 100 kWh, 80 kWh, 75 kWh, 70 kWh, 65 kWh and 60 kWh are also offered. Additionally, some municipalities provide FBE to all residential consumers, regardless of household income and electricity consumption. For example, Ekurhuleni metropolitan municipality provided 100 kWh of FBE to all residential Tariff A consumers in 2007/2008 and 2008/2009 financial years (Ekurhuleni, 2008).[10] On the other hand, and more in line with the goal of FBE, some municipalities only provide FBE if the household is registered in the indigent programme, and changed to prepaid meters.

3. Data

3.1. Data Description

This study uses data from the SA IES 2010/2011 conducted by Statistics South Africa from September 2010 to August 2011 (Stats SA, 2012b). The SA IES is a cross-sectional survey conducted every five years. Its sampling frame is based on the master sample of South African census enumeration areas; in this case, the 2001 Population Census enumeration areas, as the 2011 Census frame was not ready at that time. The SA IES 2010/2011 data provide detailed income, expenditure and demographic information on 25 328 households throughout South Africa. Personal level information (like age, gender, race, marital status, occupation, employment status and income of each person in a household) is also available. However, our focus is on the head of the household, when compiling this information for each household. After merging the information together across the different survey files, only 25 015 household samples remained. In some households, there was no clear indication of the head; we also removed the households in which the head was younger than 15.

For the present analysis, only households connected to the electricity grid are considered – out of the 25 015 households, 22 106 are grid-connected (88.37%) and 2 861 are not connected (11.44%), while 48 (0.19%) are unspecified. Unfortunately, in a number of cases, it was also not possible to separate electricity cost from water cost; a number of municipalities present customers with a consolidated bill. In a number of additional cases, survey respondents are not responsible for their own electricity accounts, and, thus, they did not report separate electricity expenditures. These households were also removed from the analysis. Missing data on important variables, such as education, access to piped water and flush toilets, dwelling type, receipt of FBE, ownership of property and appliances etc., resulted in a final effective sample of 16 851; 8 164 households out of 25 015 have been dropped. To see if dropping appears to be selective, and, thus might affect the empirical analysis, we compare the means across the retained and dropped samples, as shown in Table A.1. Although there are differences, the means from the separated samples fall within one standard deviation of the other sample's means, and, thus, dropping these observations is unlikely to have a strong influence on the reported results.

[10] Tariff A is a lower-end use tariff plan, and is available for single-phase 230 V and multiphase 400/230 V connections with a capacity of up to 80 A per phase. This tariff suits low consumption domestic and micro business customers (Ekurhuleni, 2008).

Although the number of household controls available is an advantage, the SA IES 2010/2011 does not include information on electricity prices. To accommodate this limitation, NERSA approved municipal tariffs for 2010/2011 have been used in this study. According to the NERSA tariff database, the municipal electricity tariff for 2010/2011 is regulated for indigent, prepaid and conventional metering households, separately. The indigent tariff is applied for poor households, who have been registered in the National Indigent Policy programme; the prepaid tariff is applied for prepaid meter households, while the rest are subject to conventional tariffs. The SA IES dataset includes a unique identification (ID) number for each household, and the first three digits of the ID indicate the municipality in which the household resides,[11] but the data do not indicate who is registered in the National Indigent Database. In other words, it is possible to match the appropriate NERSA approved municipal tariff for 2010/2011 to the household based on an assumption about indigents. Thus, we assign the indigent tariff to households who receive only FBE; there are 214 such households. There are a number of 15 128 households using prepaid meters; the rest 9 673 households are assigned conventional tariffs. For those missing municipalities in the NERSA approved tariff list, we use tariffs from district municipalities instead.

In the SA IES 2010/2011, electricity expenditure for each household is captured in four separate columns: "water and electricity", "electricity", "prepaid" and "free basic electricity".

- "water and electricity" is for households with consolidated water and electricity bills. Since it is not possible to split electricity out of the bill, these households are dropped.
- "electricity" (Elec): for households with conventional meters.
- "prepaid" (Prepaid): for households with prepaid meters.
- "free basic electricity" (FBE): for households whose utility bill reports the value of FBE.

This information underscores the description in Table 2 for matching the NERSA tariff to each household.

Table 2 about here

In addition to the different tariff groups, there are three types of tariff structures according to the NERSA approved tariff list for 2010/2011: the single rate, the single rate with a basic charge and the incline block tariff (IBT) (Table 3). According to the matched results, 63% of the households are assigned the approved single tariff. A few municipalities apply a single electricity rate with a basic charge – to recover distribution and billing-related costs (including the electrical distribution system, the meter, postage, customer record-keeping, meter servicing and reading). 3 019 households (12%) face this tariff structure. The IBT mechanism divides electricity prices into several blocks, and, thus, is a nonlinear tariff; the first block of electricity is priced lowest, and there are 2-4 blocks. Roughly 19% of the licensed municipalities have implemented this tariff structure (DOE, 2011). For households in municipalities

[11] The electricity supplier for residential customers is either Eskom or municipality in South Africa. In the SA IES data, it is not possible to separate Eskom direct customers from municipal customers. Hence, we apply the NERSA approved municipal tariff for the entire sample without considering the Eskom tariff during the matching process.

following the IBT, we assign the average of the approved tariffs across all of the blocks, as a proxy for the average domestic tariff these households face (25% of households). We also created a binary indicator for households under a nonlinear tariff structure: the IBT or a single rate with a basic charge.

Table 3 about here

The SA IES does not capture electricity consumption in kWh. Rather, the survey captures expenses on electricity for each household. Therefore, we take electricity expenditure as our dependent variable and calculate the price and income elasticities of demand accordingly. Since only expenditures for substitute fuels are recorded in the data, it is not possible to estimate cross-price elasticities. [12] Instead, we estimate cross effects of substitute fuels by including both a dummy for the purchase of and expenditure on substitute fuels. Since the SA IES 2010/2011 took place over a period of twelve months, all reported expenditure data have been inflated/deflated to March 2011 prices using the consumer price index (CPI).

3.2. Variables

The variables used in the analysis are listed in Table 4. The dependent variable is monthly household electricity expenditure, while *nonlinear* is the binary indicator for nonlinear tariff structure. The SA IES 2010/2011 data captured the value of FBE, or the amount of money FBE is worth, for households, whose utility bill indicates the value of FBE received, although no payment for the "value". Since the FBE is recorded and counted as both in-kind income and in-kind consumption for the household, the FBE value has not been incorporated into household electricity consumption expenditure.[13] If the households know they are receiving FBE, they are indicated as receiving FBE, represented by *fbe*. As suggested above, to accommodate substitute fuels in the analysis, we include expenditures on gas, liquid and solid fuels. Specifically, in the model, we include both an indicator of purchase of substitute fuels, along with the square root of actual expenditure.[14]

Table 4 about here

As implied from our preceding discussions, a number of household-level variables are also included. For example, we include socio-demographic characteristics (like age, gender, race and the highest level of education level completed by the household head). Other controls relate to the dwelling, such as the total number of rooms in the dwelling, dwelling type, settlement type, access to piped water and a flush toilet, as well as ownership of the dwelling. Additional variables included relate to concepts of energy need, as well as wealth. For example, we consider the ownership of electrical appliances listed in the survey: radio, stereo/HiFi, television set, DVD (digital video disc) player,

[12] Although the South African Energy Price Report 2011 (DoE, 2013) provides some price data, it is very limited. For instance, the energy price report only has one gas price per month and monthly paraffin prices for inland and coastal areas. For solid fuels, only annual average prices of coal are captured. There is not enough variation in price information from this report to merge it to households in the same way that we have done for the electricity prices.

[13] We also incorporated reported FBE values into the calculation of household electricity expenditure in a further analysis. There are no evident differences from the results we report. Further results are available from the authors.

[14] The square root is preferred, as using the natural logarithm, when zero alternative fuel expenditure is reported by approximately 90% of the households, would yield too few observations.

refrigerator/freezer, stove,[15] microwave oven, washing machine, computer, camera, cellphone, landline phone, DStv (digital satellite television), internet service and power driven tools. Considering climate conditions are also energy consumption drivers, we include *winter* and *summer* indicators to capture seasonal fluctuations in electricity consumption. Finally, in order to consider provincial differences in electricity consumption, provincial dummy variables are included.

4. Methodology

The demand for a good or service is determined by the price of the good or service, consumer's income and preferences. Thus, electricity price and household income are indispensable factors to be considered. In terms of household electricity consumption, a consumer's preference can be represented by variables related to household electricity consumption behaviours. Household electricity demand is modeled as

$$Y = f(p, I, F, D, H), \tag{1}$$

where Y denotes monthly expenditure on electricity consumption, p is electricity price, I represents monthly household income, F denotes substitute fuels for household use, D covers demographic characteristics and H represents variables related to the dwelling.

The econometric model used in this analysis considers the presence of zero electricity consumption expenditure households in the data, but only considers households connected to the grid and able to access electricity. Roughly 5.6% of the electrified households have zero expenditure on electricity. Zero expenditure may arise for the following reasons: the household is connected but can not afford electricity; the household has received FBE, does not want/need to consume more electricity, and we record their expenditure as zero. Out of the 948 households with zero electricity consumption expenditure, 23.4% have received FBE; these zero values are observed and represent actual outcomes, rather than representing missing values or potential outcomes. According to Dow and Norton (2003), a two-part model (2PM) is appropriate in this case.

The 2PM separates the dependent variable into two parts: "$Y > 0$" and "$Y|Y > 0$" (Duan et al., 1983, 1984). For the first part, we assume a standard probit for the probability the household has positive electricity consumption expenditure

$$\Pr[Y > 0|X] = \Phi(X\beta_1), \tag{2}$$

where $\Pr[\cdot]$ denotes probability; $\Phi(\cdot)$ is the Cumulative Normal Distribution Function (CDF); $Y > 0$ is a binary indicator for positive electricity consumption expenditure. X is a vector of independent variables, which affect the probability of household electricity consumption, and β_1 is a vector of associated parameters to be estimated.

[15] Unfortunately, stove includes gas, electric or paraffin style stove, and it is not possible to separate them. However, as already noted, only a small portion of households record expenditures on gas (1%) and/or paraffin (7.8%); hence we are willing to assume a stove is more than likely electric. Furthermore, stove ownership does, at least partially relate to household wealth, and, therefore it should be included.

The second part is specified as an ordinary least squares (OLS) regression of the logged dependent variable $\ln(Y|Y > 0, X)$, conducted on the electricity consuming subset.

$$E[Y|Y > 0, X] = X\beta_2 + E[\varepsilon|Y > 0, X], \tag{3}$$

where X is the same vector of independent variables for Eq. (2); β_2 is a vector of associated parameter estimates; ε is an error term. Following Dow and Norton (2003), normal homoskedastic errors ε and $E[\varepsilon|Y > 0, X] = 0$ are assumed. We use the STATA command, "twopm" (Belotti et al., 2015), to calculate marginal effects of the 2PM. In our setting, which has stratified random sampling, we need to apply a nonparametric bootstrap to calculate the standard errors for marginal effects of the 2PM (Belotti et al., 2015). However, it should be noted that the second part is based on $\ln Y = \ln p + \ln q$; we observe both expenditure (Y) and local prices (p), but not the quantity (q). There are two features to keep in mind in this setting. First, q is expected to fall when prices rise; therefore, an increase in price will only raise total expenditure, if the quantity does not fall fast enough (i.e., if the price elasticity is less than one). Second, the price elasticity of demand, conditional on positive electricity expenditure, is given by $\beta_{2,\ln p} - 1$,[16] while the income elasticity of conditional demand is given by $\beta_{2,\ln I}$. Furthermore, the marginal effects in the full model are based on re-transformed data, i.e., Y, such that the marginal effect of, for example, $\ln p$ or $\ln I$, are expenditure semi-elasticities, rather than demand elasticities.

5. Empirical Results

5.1. Prices and Incomes

Our primary interest is in the price and income elasticities of electricity demand; thus, we focus on those results for the 2PM, which are available in Table 5. This table contains three sets of estimates: one for all households and two for a reduced set of households. The reduction in numbers, as noted in the data section, is primarily due to the use of additional controls, grid connection and access to FBE. Thus, the two reduced sample estimates allow us to compare the elasticities with and without additional controls. The results of the second-stage OLS (Columns (3)-(4) of Table 5) outline the effects of price and income on conditional electricity demand. They show that electricity demand is normal, but income inelastic. Income elasticity falls from approximately 0.4, when there are no controls, to 0.1, when additional household controls are included. Furthermore, conditional electricity demand is reduced by higher prices, but the reduction is not always elastic. For the entire sample, an increase in the price of 10% is expected to reduce conditional demand by 11.2%. However, those results also incorporate households without access to the grid, and, therefore, are not expected to be representative of electricity demand. After eliminating such households, a 10% increase in the price of electricity is expected to reduce its demand by 11.6%. Once additional household controls are included, the price elasticity drops; a 10% increase in the price is expected to reduce demand by 8.9%. The price

[16] We define $\beta_{2,z}$ to the parameter on variable z in Eq. (3).

elasticity suggests that consumption does respond to prices; however, the household sector is found to have inelastic demand, once the full set of controls are incorporated. Our results suggest that despite the fact that households in our sample were recently subjected to an electricity crisis, price-responsiveness has fallen; Anderson (2004) estimated an elasticity of -1.35 using data from the year 2000. However, as we discuss below, that can be at least partly attributable to the availability of FBE.

Table 5 about here.

Despite these general results, households in South Africa are more likely to buy electricity in areas with higher prices, as shown in Columns (1)-(2) of Table 5 – results that are also in agreement with Anderson (2004). For all estimation samples, prices are higher for those purchasing electricity than those who do not; see Table 6. Specifically, consistent with Jack and Smith (2015), who note that a large proportion of residential electricity connections use prepaid meters, households accessing power via prepaid units dominate the sample. Furthermore, they face the highest average price, while those with conventional electricity – those who purchase their electricity post-pay – face a lower price; see Table 7. That difference translates into the differences seen in Table 6. However, we did undertake further investigation, thinking the difference might be location dependent: electricity prices might be higher in wealthier areas that are also more likely to purchase electricity. Thus, we re-ran the model with area-specific controls related to household characteristics, such as income, wealth and education – specifically, we included local-level means of all control variables – in order to account for possible correlation between prices and municipality attributes. Those results, shown in Table A.2, suggest there is some correlation between price and municipal attributes, and that they affect both the probability of purchase and conditional demand. However, they do not change the signs or values in any meaningful way.

Tables 6 and 7 about here.

Previous research in South Africa – see Table 1 – finds income elasticities ranging from 0 to 1.673 and price elasticities ranging from −1.35 to 0.298, although these studies are not only focused upon residential electricity consumption. Internationally, a smaller spread in elasticities is observed in the literature; income elasticities lie between 0 and 0.23, see Reiss and White (2005) and Branch (1993), while price elasticities lie between −1.32 (Bernard et al., 2011) and −0.08 (Alberini and Filippini, 2011). These studies, unlike their South African counterparts, are only for the residential sector, which probably explains the smaller spread in values. Our estimates lie within the ranges observed both nationally and internationally.

5.2. Additional Determinants

The marginal effects from the 2PM related to non-price and non-income controls are presented in Table 8. The nuance in results support our use of the 2PM. Both the nonlinear tariff structure (which we interact with the log of the price) and FBE influence the probability that households purchase electricity and total (log) expenditure, conditional on purchase. The nonlinear structure reduces the probability of purchase, while FBE increases the probability by 1.6%. As it is designed to do, FBE reduces (log) expenditure, conditional on purchasing electricity. Despite the opposing effects in each of the two-parts, the overall effect of FBE is a reduction in electricity expenditure in households. On the other hand, the nonlinear structure operates in the opposite direction of the electricity price. In other words, price responsiveness for nonlinear tariff consumers is smaller than for other consumers. Recalling the large proportion of prepaid households in our sample, along with Jack and Smith's (2015) assertion that prepaid meters offer improved flexibility, the result makes sense. Overall, however, the results also suggest that a nonlinear tariff structure works as expected; in areas with both higher prices and nonlinear pricing, households spend less on electricity.

In addition to expecting own prices and freely available electricity to matter, substitute energy options should also determine electricity demand. Although it would be preferable to incorporate the prices of alternatives, we were not able to do so, as described above. Therefore, we incorporated actual expenditure and indicators of positive expenditure, focusing on solid fuels (primarily candle and firewood), (natural) gas and liquid fuels (primarily paraffin). With respect to these substitutes, the correlation between expenditure and the probability of purchase, conditional demand and full demand was economically small, but suggestive of energy-mixing at the household level. Specifically, total electricity expenditure is higher for households spending more on either liquid or solid fuels (Columns (5)-(6) of Table 8). When examining the indicators, the results are more suggestive of substitution. Households purchasing either liquid or solid fuels had a lower probability of purchasing electricity (about 3-4%), and the reduction was statistically significant for solid fuels. Furthermore, purchasing liquid fuels statistically significantly reduced the conditional demand for electricity. In combination, electricity expenditure is approximately 20% lower amongst households purchasing either solid or liquid fuels, and this reduction is statistically significant.

The alternative energy source results are quite suggestive. Firstly, recall that our price elasticity estimates point to a reduction, compared to previous studies. Secondly, as outlined above, we find evidence of both energy-mixing – more spending on any type of energy raises expenditure on other sources – and energy substitution – using any type of alternative source reduces electricity expenditure. In combination, these features suggest that households are attempting to use alternative sources of energy to limit their dependence on electricity. Although some of the reduction in price elasticity can be tied to FBE, it can also be related to a desire to limit dependence. We expect households to replace electricity with additional energy sources, when that can be easily accomplished. Thus, there will be less flexibility in the remaining electricity needs, and, therefore, a reduced price response. Both of these empirically supported observations are understandable, given South African household experiences with previous energy crises and rolling blackouts.

Further, our results suggest that larger households living in larger urban homes, especially if owned, are more likely to purchase electricity. We also find evidence that appliance ownership, especially radio, TV, refrigerator/freezer and stove ownership are associated with an increased probability of purchasing electricity. With respect to total consumption on electricity, which we see in Columns (5)-(6) of Table 8, nearly all appliances lead to increased total electricity expenditure, as well as on conditional expenditure (Columns (3) and (4)), although refrigerators/freezers and stoves have a larger impact on total expenditure, than other appliances. Similarly, as with the probability of purchase, household size, actual size of the dwelling (in number of rooms) and urban locale are associated with increased expenditure. Given the nature of the analysis, the aforementioned determinants have the same qualitative effect on electricity demand. In other words, electricity demand is higher in appliance-rich large houses and households, but lower in FBE households and those facing higher average prices in a nonlinear tariff structure area.

The results related to education were not entirely expected. Each of the estimated marginal effects on the probability of purchase, which are relative to a non-educated head, is negative, while some – secondary and matric plus – are statistically significantly so. We expected education to correlate with wealth and income, and, therefore, be associated with an increased purchase probability. However, it is important to recall that we have incorporated income and various measures of wealth, measured by number of rooms and ownership of appliances. Therefore, once we control for income and appliance-based electricity need, education no longer matters in the probability of purchase. Furthermore, we see that education is not an important determinant of total expenditure (or conditional expenditure), once controlling for other factors.

In general, the results across both parts of the 2PM work in opposite directions, see Columns (1)-(4) of Table 8. In addition to the results already described, the marginal effects of *pipe water* and *flush toilet* – the household has access to piped water and flush toilet sanitation – are statistically significant under both parts, which means they are important determinants of both purchase and quantity (conditional on purchase). However, the full two-part model estimates (in Columns (5)-(6) of Table 8) are insignificant; thus, the probability of buying and expenditure conditional on purchase cancel each other in the full model. Differences in estimates across the first and second stage demonstrate the advantage of the 2PM. It separately takes into account both the decision to buy electricity and the expenditure, conditional on purchase, because these decision processes may not be the same.

5.3. Policy Discussion

Unfortunately, South Africa's apartheid past can be observed in these results. Non-black households consume more electricity, and that difference is made worse by appliance differences (not reported, but extensive across race groups). In terms of policy, FBE was designed to partly alleviate inequality in the access to electricity, and, to some degree, appears to have made at least some difference: increasing access and alleviating the burdens associated with purchase. However, since the FBE policy does not aim to reduce electricity consumption (rather, it aims to increase it), and the lack of clarity in the data regarding which households may have received FBE, one should be careful, when interpreting the relationship between FBE and electricity use we found. The racial differences, unfortunately, are underscored by South Africa's historical legacy, and they present big challenges.

Because electricity is an important input for the economic growth needed to potentially reverse apartheid's racial differences, and, given the supply limitations discussed previously, there remains a need to reign-in residential demand. Doing so will expand availability for the primary and secondary production sectors of the economy, and, according to our results, this might be achieved by (a) focusing attention on efficient electrical appliances, (b) increasing prices and/or extending access to prepaid meters and (c) increasing the transparency and focus of the FBE policy.

Electrical appliances were found to increase the demand for electricity, and, therefore, higher efficiency appliances are expected to reduce demand; as noted above, De la Rue du Can et al. (2013) present evidence that the residential sector has delivered 76% (2 333 MW) of all peak demand savings. Similar programs aimed at reducing the purchase price of energy efficient appliances such as previous solar water heater and residential heat pump rebates would be expected to further reduce electricity demand and expenditure.

With respect to price, electricity demand is price inelastic, once the full set of household controls are incorporated, while nonlinear tariffs further reduce price responsiveness. Thus, an alternative that focuses consumer attention on the price they pay – requiring prepaid meters, for example – is likely to have a larger impact. However, the price inelastic nature of electricity demand implies that increased prices will increase household expenditure on electricity, at least for those who purchase, eroding household purchasing power. Given the legacy of apartheid, which led to wide racial disparities in welfare, electricity price increases could further exacerbate those differences. However, the post-apartheid government has developed the FBE program to offset some of those problems. Available data suggest that this program is not applied in the same manner in all places, and, more concerning, may not even be applied directly to relatively poorer households. Thus, it is necessary to make FBE more transparent, since it is applied to the benefit of poor households. If the electricity price keeps increasing, then the FBE will be able to offset that rise in price.

6. Conclusions

This study investigates the determinants of South African residential electricity consumption in order to shed some light on the demand for electricity in developing countries. The study is based on data from the SA IES 2010/2011. The results uncover a wide range of determinants, whose contribution to the probability of buying electricity and consumption conditional on purchase are often opposite each other. The result that determinants might affect the probability of purchase in a different direction than conditional purchases supports our use of the two-part model in this analysis.

Economically, expectations associated with demand were upheld. In terms of South Africa's energy problems and need for economic growth, the results present challenges. Increased growth means increased income, and, therefore, increased electricity demand at a time when new power generation facilities are not yet online. Meanwhile, increased prices are expected to yield consumption reductions with all else equal; yet, price increases may negatively impact household welfare. Thus, a delicate balance will need to be struck and maintained. We find that the electricity price and household income are major economic factors, and, for the most part, accord with economic expectations. A higher electricity price contributes to reduced consumption, while electricity is a normal good. Both price and income elasticities are inelastic, once the full range of additional determinants is incorporated in the model, and are within the range of estimates available in the developing country literature. Furthermore, our results point to a reduction in the price elasticity of demand, compared to previous studies. With regards to alternative energy sources, we also find evidence of both energy-mixing – more spending on any type of energy raises expenditure on other sources –

and energy substitution – using any type of alternative source reduces electricity expenditure. In combination, these features suggest that these households are attempting to use alternative energy sources to limit their dependence on electricity, which is a reasonable response to previous energy crises. Unfortunately, racial differences that can be tied to South Africa's historical legacy remain a feature. In addition to this set of expected results, we find that our measures of electricity need and wealth are important determinants of electricity consumption. Households with more persons, a larger number of rooms and more appliances (of nearly any kind) are found to spend more on electricity. Similarly, households residing in urban areas consume more electricity than households living elsewhere.

Although a large number of determinants were uncovered, and the economic expectations associated with demand were upheld by the research, further research is needed. The preceding analysis was limited to those connected to the grid, partly because households not connected would not generally be in a position to use electricity; they would be unlikely to own appliances, for example. However, as the grid is extended, more households will have access. At this stage, we are not in a position to say anything about the potential effect of grid extension on overall residential electricity consumption. Therefore, further research into the effect of rolling out the national electricity grid on household electricity use, and even other forms of energy, is needed.

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References

Alberini, A., Filippini, M., 2011. Response of residential electricity demand to price: the effect of measurement error. Energy Economics 33 (5), 889–895.

Amusa, H., Amusa, K., Mabugu, R., 2009. Aggregate demand for electricity in South Africa: ananalysis using the bounds testing approach to cointegration. Energy Policy 37 (10), 4167–4175.

Anderson, P., July 2004. Household consumption of electricity: an estimation of the price and income elasticity for pre-paid users in South Africa. Master's thesis, University of Cape Town.

Barnes, R., Gillingham, R., Hagemann, R., 1981. The short-run residential demand for electricity. The Review of Economics and Statistics 63 (4), 541–552.

Bayliss, K., June 2008. Lessons from the South African electricity crisis. International Policy Centre for Inclusive Growth Report 56.

Bedir, M., Hasselaar, E., Itard, L., 2013. Determinants of electricity consumption in Dutch dwellings. Energy and Buildings 58, 194–207.

Bekker, B., Eberhard, A., Gaunt, T., Marquard, A., 2008. South Africa's rapid electrification programme: policy, institutional, planning, financing and technical innovations. Energy Policy 36 (8), 3125–3127.

Belotti, F., Deb, P., Manning, W. G., Norton, E. C., 2015. twopm: Two-part models. The Stata Journal 15 (1), 3–20.

Bernard, J.-T., Bolduc, D., Yameogo, N.-D., 2011. A pseudo-panel data model of household electricity demand. Resource and Energy Economics 33 (1), 315–325.

Branch, E. R., 1993. Short run income elasticity of demand for residential electricity using consumer expenditure survey data. Energy Journal 14 (4), 111–121.

Brounen, D., Kok, N., Quigley, J. M., 2012. Residential energy use and conservation: economics and demographics. European Economic Review 56 (5), 931–945.

De la Rue du Can, S., Letschert, V., Leventis, G., Covary, T., Xia, X., August 2013. Energy efficiency country study: Republic of South Africa. LBNL Report 6365E, Lawrence Berkeley National Laboratory.

Dinkelman, T., 2011. The effects of rural electrification on employment: new evidence from South Africa. American Economic Review 101 (7), 3078–3108.

DME, 2003. Guidelines for the introduction of Free Basic Electricity services. Tech. rep., Department of Minerals and Energy.

DOE, 2011. Annual Report 2010/2011. Tech. rep., Department of Energy.

DOE, July 2012a. National Energy Efficiency Strategy of the Republic of South Africa. second review, Department of Energy.

DOE, 2012b. A survey of energy-related behaviour and perceptions in South Africa. Tech. rep., Department of Energy: the Residential Sector.

DoE, March 2013. South African Energy Price Report 2011. Tech. rep., Department of Energy.

DOE, September 2016. Post-2015 National Energy Efficiency Strategy of the Republic of South Africa. Tech. rep., Department of Energy.

Dow, W. H., Norton, E. C., 2003. Choosing between and interpreting the Heckit and Two-part models for corner solutions. Health Services & Outcomes Research Methodology 4 (1), 5–18.

DPLG, 2009. Guidelines for the implementation of the National Indigent Policy by municipalities. Tech. rep., Department of Provincial and Local Government.

Duan, N., Manning, W. G., Morris, C. N., Newhouse, J. P., 1983. A comparison of alternative models for the demand for medical care. Journal of Business and Economic Statistics 1 (2), 115–126.

Duan, N., Manning, W. G., Morris, C. N., Newhouse, J. P., 1984. Choosing between the sample-selection model and the multi-part model. Journal of Business and Economic Statistics 2 (3), 283–289.

Ekurhuleni, May 2008. 2008/09 budget speech. Tech. rep., Ekurhuleni metropolitan municipality.

Eskom, 2007. Annual Report 2007. Tech. rep., Eskom.

Eskom, 2011. Integrated Report 2011. Tech. rep., Eskom.

Eskom, 2014. Integrated Report 2014. Tech. rep., Eskom.

Eskom, 2015. Integrated Report 2015. Tech. rep., Eskom.

Fell, H., Li, S., Paul, A., 2014. A new look at residential electricity demand using household expenditure data. International Journal of Industrial Organization 33, 37–47.

Gaunt, C., 2008. Electricity distribution industry restructuring in South Africa: a case study. Energy Policy 36 (9), 3448–3459.

Halvorsen, B., Larsen, B. M., 2001. Norwegian residential electricity demand – a microeconomic assessment of the growth from 1976 to 1993. Energy Policy 29 (3), 227–236.

Harris, T., Collinson, M., Wittenberg, M., 2017. Aiming for a moving target: the dynamics of household electricity connections in a developing context. World Development 97, 14–26.

Heltberg, R., 2004. Fuel switching: evidence from eight developing countries. Energy Economics 26 (5), 869–887.

Hondroyiannis, G., 2004. Estimating residential demand for electricity in Greece. Energy Economics 26 (3), 319–334.

Inglesi, R., 2010. Aggregate electricity demand in South Africa: conditional forecasts to 2030. Applied Energy 87 (1), 197–204.

Inglesi-Lotz, R., 2011. The evolution of price elasticity of electricity demand in South Africa: a Kalman filter application. Energy Policy 39 (6), 3690–3696.

Inglesi-Lotz, R., 2014. The sensitivity of the South African industrial sector's electricity consumption to electricity price fluctuations. Journal of Energy in Southern Africa 25 (4), 2–10.

Inglesi-Lotz, R., Blignaut, J. N., 2011. South Africa electricity consumption: a sectoral decomposition analysis. Applied Energy 88 (12), 4779–4784.

Ito, K., 2014. Do consumers respond to marginal or average price? Evidence from nonlinear electricity pricing. American Economic Review 104 (2), 537–563.

Jack, B. K., Smith, G., 2015. Pay as you go: Prepaid metering and electricity expenditures in South Africa. American Economic Review: Papers & Proceedings 105 (5), 237–241.

Johnson, N. G., Bryden, K. M., 2012. Energy supply and use in a rural West African village. Energy 43 (1), 283–292.

Kohler, M., 2014. Differential electricity pricing and energy efficiency in South Africa. Energy 64, 524–532.

Louw, K., Conradie, B., Howells, M., Dekenah, M., 2008. Determinants of electricity demand for newly electrified low-income African households. Energy Policy 36 (8), 2812–2818.

McLoughlin, F., Duffy, A., Conlon, M., 2012. Characterising domestic electricity consumption patterns by dwelling and occupant socio-economic variables: an Irish case study. Energy and Buildings 48, 240–248.

Meyer, J. P., 2000. A review of domestic hot-water consumption in South Africa. R & D Journal 16 (3), 55–61.

Narayan, P. K., Smyth, R., 2005. The residential demand for electricity in Australia: an application of the bounds testing approach to co integration. Energy Policy 33 (4), 467–474.

National Treasury, February 2008. The Budge Review 2008. Tech. rep., National Treasury.

NERSA, 2015. NERSA report on the national free basic electricity (NFBE) for the 2015/16 financial year. Tech. rep., National Energy Regulator of South Africa.

Newbery, D., Eberhard, A., 2008. South African network infrastructure review: electricity. A paper written for National Treasury and the Department of Public Enterprises Government of South Africa.

Niu, S., Zhang, X., Zhao, C., Niu, Y., 2012. Variations in energy consumption and survival status between rural and urban households: a case study of the Western Loess Plateau, China. Energy Policy 49 (10), 515–527.

Nkambule, N. P., Blignaut, J., 2012. The external costs of coal mining: the case of the collieries supplying Kusile power station. Journal of Energy in Southern Africa 23 (4), 85–93.

O'Doherty, J., Lyons, S., Tol, R. S., 2008. Energy-using appliances and energy-saving features: determinants of ownership in Ireland. Applied Energy 85 (7), 650–662.

Pouris, A., 1987. The price elasticity of electricity demand in South Africa. Applied Economics 19 (9), 1269–1277.

Reiss, P. C., White, M. W., 2005. Household electricity demand, revisited. Review of Economic Studies 72 (3), 853–883.

Riekert, J. W., Koch, S. F., 2012. Projecting the external health costs of a coal-fired power plant: the case of Kusile. Journal of Energy in Southern Africa 23 (4), 52–66.

Sanquist, T. F., Orr, H., Shui, B., Bittner, A. C., 2012. Lifestyle factors in U.S. residential electricity consumption. Energy Policy 42, 354–364.

Stats SA, January 2012a. Energy Accounts for South Africa: 2002-2009. Tech. rep., Statistics South Africa.

Stats SA, 2012b. Income and Expenditure Survey 2010/2011. Version 2, Pretoria: Statistics South Africa [producer], 2012. Cape Town: DataFirst [distributor], 2013.

Stats SA, August 2012c. Non-financial census of municipalities for the year ended 30 june 2011. Tech. rep., Statistics South Africa.

Stats SA, 2012d. The General Household Survey 2011: statistical release. Statistics South Africa.

Tso, G. K., Yau, K. K., 2003. A study of domestic energy usage patterns in Hong Kong. Energy 28 (15), 1671–1682.

Ye, X., Xia, X., Zhang, J., 2013. Optimal sampling plan for clean development mechanism energy efficiency lighting projects. Applied Energy 112, 1006–1015.

Ye, X., Xia, X., Zhang, J., 2014. Optimal sampling plan for clean development mechanism lighting projects with lamp population decay. Applied Energy 136, 1184–1192.

Ziramba, E., 2008. The demand for residential electricity in South Africa. Energy Policy 36 (9), 3460–3466.

Table 1: Electricity consumption analysis in South Africa.

Source	Data and period	Price and income elasticities	Econometric model
Pouris (1987)	time-series, 1950-1983	LR: income 0.71, price -0.9	Unconstrained distributed lag model
Anderson (2004)	household-level, 2000	income 0.32, price -1.35	Heckman selection model
Louw et al. (2008)	household-level, 1998	income: 0.243 to 0.532	Logarithm OLS regressing model
Ziramba (2008)	time-series, 1978-2005	LR: income 0.31, price -0.04; SR: income 0.3, price -0.02	ARDL bounds testing approach
Amusa et al. (2009)	time-series, 1960-2007	LR: income 1.673, price 0.298	ARDL bounds testing approach
Inglesi (2010)	time-series, 1980-2005	LR: income 0.42, price -0.56	Engle-Granger and ECM models
Inglesi-Lotz (2011)	time-series, 1980-2005	income: 0 to 1, price: -1.077 to -0.045	Kalman filter
Inglesi-Lotz (2014)	time-series, 1970-2007	price: -1 to -0.95	Kalman filter
Jack and Smith (2015)	household-level, 2014	-	-

SR, short-run; LR, long-run.

Table 2: Tariff types by type of payment.

	Tariff type	Sample size
(1) Elec = 0, Prepaid >0	Prepaid	15 128
(2) Elec = Prepaid = FBE = 0 or Elec > 0	Conventional	9 673
(3) Elec = Prepaid =0, FBE > 0	Indigent	214
Total		25 015

Table 3: Tariff structures according to the NERSA approved list.

	Tariff structure	Sample size
Linear	Single rate	15 844
Nonlinear	Single rate with a basic charge	3 029
	Incline block tariff (IBT)	6 142
Total		25 015

Table 4: Descriptive statistics of variables (N =16 851).

Variable name	Description	Mean	Std. Dev	Min	Max
Y	monthly household electricity consumption expenditure (unit: ZAR[a])	225.352	335.153	0	10085.5
I	monthly household income (unit: ZAR)	8 396.801	13 501.620	0	175 809.8
p	electricity price (unit: c/kWh[b])	80.506	11.144	27.5	114
nonlinear	dummy: 1 if household facing following electricity tariff structure: the incline block tariff (IBT) or a single rate with a basic charge	0.318	0.466	0	1
fbe	dummy: 1 if household has received free basic electricity	0.283	0.450	0	1
Y_{gas}	Monthly household gas expenditure, including expenditures on gas supplied through either a public network or purchased in cylinders (including gas for heating purposes) (unit: ZAR)	2.74	56.59	0	6 047.92
Y_{liquid}	Monthly household expenditure on liquid fuels, including expenditures on paraffin, petrol and diesel (petrol and diesel for household use, not transport) (unit: ZAR)	7.83	63.88	0	3 276.33
Y_{solid}	Monthly household expenditure on solid fuels, including expenditures on candle, firewood bought, coal, charcoal, dung and cropwaste; not including fetched firewood and dung values (unit: ZAR)	5.14	43.35	0	1 839.42
d_{gas}	dummy: 1 if $Y_{gas} > 0$	0.01	0.10	0	1
d_{liquid}	dummy: 1 if $Y_{liquid} > 0$	0.08	0.28	0	1
d_{solid}	dummy: 1 if $Y_{solid} > 0$	0.08	0.27	0	1
hhsize	household size (number of persons in a household)	4.037	2.349	1	21
room	total number of rooms in use excluding bathrooms in a household	4.451	2.074	0	18
urban	dummy: 1 if household settles in urban formal or urban informal areas	0.628	0.483	0	1
formal	dummy: 1 if the type of main dwelling is dwelling/house or brick/concrete block structure on a separate stand or yard or on a farm; flat or apartment in a block of flats; cluster house in security complex; town house/semi-detached house; dwelling/house/flat/room in backyard; room/flatlet on a property or a larger dwelling, servants quarters/granny's flat	0.875	0.331	0	1
traditional	dummy: 1 if the type of main dwelling is traditional dwelling/hut/structure made of traditional materials	0.070	0.255	0	1
informal	dummy: 1 if the type of main dwelling is informal dwelling/shack in backyard; informal dwelling/shack not in backyard, e.g. in an informal/squatter settlement or on farm; caravan/tent	0.055	0.228	0	1
owner	dummy: 1 if household owns the property	0.896	0.306	0	1
pipe water	dummy: 1 if household has access to pipe water	0.867	0.340	0	1
flush toilet	dummy: 1 if household has access to flush toilet	0.595	0.491	0	1
winter	dummy: 1 if household is interviewed in July, August or September	0.245	0.430	0	1
summer	dummy: 1 if household is interviewed in December, January or February	0.275	0.446	0	1
age	age of household head	48.390	15.913	15	95

... continued on next page ...

Variable name	Description	Mean	Std. Dev	Min	Max
female	dummy: 1 if household head is female	0.459	0.498	0	1
African/Black	dummy: 1 if household head is African/Black	0.797	0.402	0	1
Coloured	dummy: 1 if household head is Coloured	0.115	0.319	0	1
Indian/Asian	dummy: 1 if household head is Indian/Asian	0.015	0.120	0	1
White	dummy: 1 if household head is White	0.074	0.261	0	1
no schooling	dummy: 1 if household head has no schooling	0.125	0.331	0	1
primary	dummy: 1 if the highest level of education that household head successfully completed is between Grade 0-7	0.271	0.444	0	1
secondary	dummy: 1 if the highest level of education that household head successfully completed is between Grade 8-11	0.329	0.470	0	1
matric	dummy: 1 if the highest level of education that household head successfully completed is Grade 12	0.227	0.419	0	1
matric plus	dummy: 1 if the highest level of education that household head successfully completed is higher than Grade 12, e.g. Bachelors, Honours or higher degree (Masters, PhD)	0.048	0.213	0	1
radio	dummy: 1 if household owns radio	0.546	0.498	0	1
stereo/HiFi	dummy: 1 if household owns stereo or HiFi	0.301	0.459	0	1
TV	dummy: 1 if household owns television set	0.854	0.353	0	1
DVD	dummy: 1 if household owns DVD player	0.653	0.476	0	1
refrigerator	dummy: 1 if household owns refrigerator or freezer	0.823	0.382	0	1
stove	dummy: 1 if household owns gas, electric or paraffin stove	0.908	0.289	0	1
microwave	dummy: 1 if household owns microwave oven	0.479	0.500	0	1
washing machine	dummy: 1 if household owns washing machine	0.349	0.477	0	1
computer	dummy: 1 if household owns computer	0.166	0.372	0	1
camera	dummy: 1 if household owns camera	0.115	0.319	0	1
cellphone	dummy: 1 if household owns cellphone	0.907	0.290	0	1
telephone	dummy: 1 if household owns telephone	0.142	0.349	0	1
DStv	dummy: 1 if household owns DStv	0.229	0.420	0	1
internet	dummy: 1 if household has internet service	0.060	0.238	0	1
power tool	dummy: 1 if household owns power driven tool, e.g. electricity drill	0.131	0.337	0	1
Western Cape	dummy: 1 if household residents in Western Cape province	0.128	0.334	0	1
Eastern Cape	dummy: 1 if household residents in Eastern Cape province	0.128	0.334	0	1
Northern Cape	dummy: 1 if household residents in Northern Cape province	0.051	0.220	0	1
Free State	dummy: 1 if household residents in Free State province	0.097	0.296	0	1
KwaZulu-Natal	dummy: 1 if household residents in KwaZulu-Natal province	0.127	0.333	0	1
North West	dummy: 1 if household residents in North West province	0.112	0.315	0	1
Gauteng	dummy: 1 if household residents in Gauteng province	0.115	0.319	0	1
Mpumalanga	dummy: 1 if household residents in Mpumalanga province	0.093	0.290	0	1
Limpopo	dummy: 1 if household residents in Limpopo province	0.150	0.357	0	1

[a] In March of 2011, USD 1 = ZAR 6.90. [b] c denotes cent, ZAR 1 = 100 cents.

Table 5: Marginal effects, income and price elasticities from the 2PM.

	(1)	(2)	(3)	(4)	(5)	(6)
(A) Estimates from Entire Sample						
Variable	Probit		The second-stage OLS		2PM	
	Marginal effect	Delta-method Std. Err.	Elasticity	Std. Err.	Elasticity	Bootstrap Std. Err.
ln(I)	0.030***	(0.002)	0.397***	(0.004)	0.427***	(0.012)
ln(p)	0.183***	(0.018)	-1.121***	(0.041)	-0.188***	(0.098)
constant			2.254***	(0.182)		
R^2			0.3259			
Observation	25 015		17 810		25 015	
(B) Estimates from Primary Estimation Sample						
Variable	Probit		The second-stage OLS		2PM	
	Marginal effect	Delta-method Std. Err.	Elasticity	Std. Err.	Elasticity	Bootstrap Std. Err.
ln(I)	0.005***	(0.001)	0.432***	(0.005)	0.430***	(0.011)
ln(p)	0.098***	(0.011)	-1.159***	(0.042)	-0.665***	(0.072)
constant			2.123***	(0.189)		
R^2			0.3530			
Observation	16 851		15 903		16 851	
(C) Estimates from Primary Estimation Sample with Controls						
Variable	Probit		The second-stage OLS		2PM	
	Marginal effect	Delta-method Std. Err.	Elasticity	Std. Err.	Elasticity	Bootstrap Std. Err.
ln(I)	0.001	(0.002)	0.131***	(0.005)	0.128***	(0.011)
ln(p)	0.119***	(0.011)	-0.888**	(0.039)	-0.305***	(0.069)
constant			2.356***	(0.195)		
R^2			0.5664			
Observation	16 851		15 903		16 851	

Panel A uses all households (N=25 015), while Panel B uses the primary estimation sample (N=16 851, which is the sample that arises, when additional controls are incorporated); neither sets of regressions include controls other than price and income (in their natural log). Panel C uses the primary estimation sample (N=16 851), along with additional controls. Probit contains estimates of the probability that a household purchases electricity, assuming normality. Dependent variable in OLS model is ln monthly electricity expenditure. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 6: Average price paid by value of electricity expenditure.

	$Y > 0$	$Y = 0$	$Y \geq 0$
$\overline{p}$	80.69	77.46	80.51
N	15 903	948	16 851

Mean price given to households separated by electricity expenditure levels.

Table 7: Average price paid by type of payment.

	Prepaid	Conventional	Indigent	Total
$\overline{p}$	81.23	77.82	67.16	80.51
N	13 543	3 222	86	16 851

Mean price given to households in different data subsets.

Table 8: Marginal effects from the 2PM.

	(1)	(2)	(3)	(4)	(5)	(6)
Variable	Probit		The second-stage OLS		2PM	
	Marginal effect	Delta-method Std. Err.	Marginal effect	Std. Err.	Marginal effect	Bootstrap Std. Err.
nonlinear∗ln(*p*)	-0.006***	(0.001)	0.011***	(0.003)	-0.018**	(0.006)
fbe	0.016***	(0.004)	-0.224***	(0.012)	-0.132***	(0.023)
$\sqrt{Y_{gas}}$	0.000	(0.002)	0.006	(0.006)	0.006	(0.014)
$\sqrt{Y_{liquid}}$	0.003	(0.002)	0.004	(0.003)	0.019**	(0.007)
$\sqrt{Y_{solid}}$	0.005*	(0.002)	-0.004	(0.004)	0.023*	(0.011)
d_{gas}	0.011	(0.038)	0.084	(0.094)	0.134	(0.210)
d_{liquid}	-0.026	(0.014)	-0.085*	(0.033)	-0.207**	(0.066)
d_{solid}	-0.040**	(0.014)	0.002	(0.031)	-0.199**	(0.067)
ln(*hhsize*)	0.011***	(0.003)	0.093***	(0.009)	0.142***	(0.017)
ln(*room*)	0.018***	(0.004)	0.210***	(0.012)	0.287***	(0.023)
urban	0.024***	(0.007)	0.078***	(0.020)	0.193***	(0.042)
traditional	0.006	(0.008)	-0.070**	(0.023)	-0.038	(0.046)
informal	-0.005	(0.007)	0.069**	(0.024)	0.039	(0.043)
owner	0.014**	(0.005)	-0.135***	(0.018)	-0.059	(0.032)
pipe water	0.013*	(0.006)	-0.050**	(0.017)	0.018	(0.034)
flush toilet	-0.040***	(0.007)	0.215***	(0.019)	0.003	(0.040)
winter	0.002	(0.004)	-0.002	(0.012)	0.007	(0.024)
summer	-0.001	(0.004)	-0.021	(0.012)	-0.025	(0.023)
ln(*age*)	0.001	(0.006)	0.010	(0.016)	0.013	(0.031)
female	-0.001	(0.004)	-0.036***	(0.011)	-0.040	(0.020)
Coloured	-0.009	(0.007)	0.180***	(0.022)	0.124**	(0.038)
Indian/Asian	0.034	(0.019)	0.479***	(0.044)	0.620***	(0.112)
White	-0.009	(0.008)	0.485***	(0.027)	0.415***	(0.051)
primary	-0.005	(0.007)	0.012	(0.017)	-0.014	(0.037)
secondary	-0.016*	(0.007)	0.010	(0.018)	-0.070	(0.038)
matric	-0.010	(0.007)	0.026	(0.020)	-0.025	(0.040)
matric plus	-0.029**	(0.009)	0.056	(0.028)	-0.091	(0.054)
radio	0.008*	(0.004)	-0.003	(0.010)	0.035	(0.020)
stereo/HiFi	0.007	(0.004)	0.055***	(0.012)	0.085***	(0.023)
TV	0.012*	(0.005)	0.099***	(0.018)	0.153***	(0.032)
DVD	0.004	(0.004)	0.050***	(0.013)	0.068**	(0.024)
refrigerator	0.022***	(0.005)	0.169***	(0.017)	0.267***	(0.030)
stove	0.023***	(0.006)	0.113***	(0.019)	0.219***	(0.034)
microwave	0.006	(0.005)	0.133***	(0.013)	0.154***	(0.027)
washing machine	0.001	(0.005)	0.124***	(0.015)	0.123***	(0.029)
computer	-0.009	(0.006)	0.150***	(0.018)	0.098**	(0.034)
camera	0.003	(0.007)	0.063**	(0.021)	0.072	(0.041)
cellphone	0.002	(0.006)	0.100***	(0.019)	0.104**	(0.033)
telephone	-0.006	(0.006)	0.126***	(0.019)	0.088*	(0.036)
DStv	0.002	(0.005)	0.138***	(0.015)	0.140***	(0.031)
internet	-0.013	(0.009)	0.061*	(0.028)	-0.009	(0.049)
power tool	-0.002	(0.006)	0.072***	(0.018)	0.057	(0.036)
Western Cape	0.062***	(0.007)	-0.078**	(0.025)	0.234***	(0.042)
Eastern Cape	0.046***	(0.007)	-0.200***	(0.023)	0.041	(0.041)
Northern Cape	0.027***	(0.008)	-0.104***	(0.029)	0.037	(0.052)
Free State	0.086***	(0.008)	-0.137***	(0.023)	0.298***	(0.047)
KwaZulu-Natal	0.068***	(0.007)	0.180***	(0.024)	0.506***	(0.044)
North West	0.074***	(0.008)	-0.069**	(0.024)	0.303***	(0.046)
Mpumalanga	0.076***	(0.008)	-0.048*	(0.024)	0.331***	(0.047)
Limpopo	0.075***	(0.008)	-0.159***	(0.024)	0.220***	(0.051)
constant			2.356***	(0.195)		
R^2			0.5664			
Observation	16 851		15 903		16 851	

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

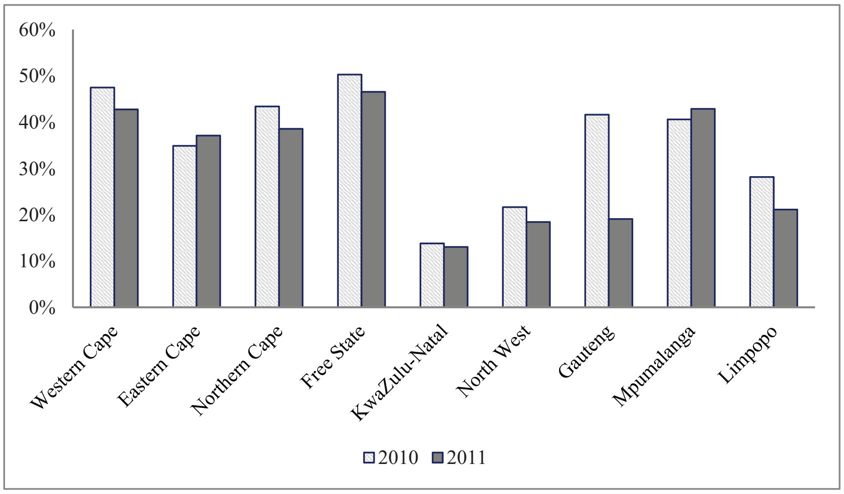

Figure 1: Proportion of consumer units receiving FBE services over the period 2010 and 2011.

Appendix A

Table A.2: Marginal effects from the 2PM with additional controls of municipal-level means of the independent variables.

Variable	Probit		The second-stage OLS		2PM	
	Marginal effect	Delta-method Std. Err.	Marginal effect	Std. Err.	Marginal effect	Bootstrap Std. Err.
ln(I)	0.003	(0.002)	0.121***	(0.005)	0.128***	(0.011)
ln(I_mean)	-0.029**	(0.011)	0.097**	(0.031)	-0.053	(0.070)
ln(p)	0.462***	(0.022)	-0.389***	(0.105)	1.942***	(0.169)
ln(p_mean)	-0.383***	(0.026)	0.529***	(0.116)	-1.415***	(0.187)
$nonlinear{*}\ln(p)$	-0.019***	(0.001)	0.031***	(0.006)	-0.066***	(0.009)
$nonlinear\_mean{*}\ln(p\_mean)$	0.026***	(0.002)	-0.026**	(0.008)	0.106***	(0.014)
fbe	0.018***	(0.004)	-0.206***	(0.013)	-0.105***	(0.025)
fbe_mean	-0.000	(0.013)	-0.038	(0.036)	-0.037	(0.083)
$\sqrt{Y_{gas}}$	-0.001	(0.002)	0.005	(0.006)	-0.000	(0.016)
$\sqrt{Y_{gas}\_mean}$	-0.008**	(0.003)	0.029***	(0.008)	-0.011	(0.016)
$\sqrt{Y_{liquid}}$	0.003*	(0.002)	0.005	(0.003)	0.020**	(0.007)
$\sqrt{Y_{liquid}\_mean}$	-0.005*	(0.002)	-0.010	(0.006)	-0.032**	(0.012)
$\sqrt{Y_{solid}}$	0.004*	(0.002)	-0.002	(0.004)	0.021	(0.010)
$\sqrt{Y_{solid}\_mean}$	0.002	(0.003)	-0.001	(0.007)	0.007	(0.016)
d_{gas}	0.037	(0.035)	0.049	(0.094)	0.229	(0.232)
d_{gas}_mean	0.058	(0.147)	-0.056	(0.452)	0.239	(0.799)
d_{liquid}	-0.026*	(0.013)	-0.115***	(0.033)	-0.241***	(0.065)
d_{liquid}_mean	0.085	(0.058)	0.423**	(0.158)	0.825*	(0.335)
d_{solid}	-0.038**	(0.013)	0.002	(0.031)	-0.188**	(0.067)
d_{solid}_mean	-0.109	(0.062)	-0.324*	(0.161)	-0.848*	(0.374)
ln($hsize$)	0.009**	(0.003)	0.099***	(0.009)	0.140***	(0.017)
ln($hsize\_mean$)	-0.032	(0.026)	0.109	(0.073)	-0.056	(0.171)
ln($room$)	0.016***	(0.004)	0.207***	(0.012)	0.273***	(0.023)
ln($room\_mean$)	-0.001	(0.026)	0.164*	(0.071)	0.150	(0.155)
urban	0.025***	(0.008)	0.104***	(0.023)	0.223***	(0.047)
urban_mean	0.010	(0.022)	-0.065	(0.060)	-0.013	(0.142)
traditional	0.015	(0.009)	-0.092***	(0.025)	-0.011	(0.049)
traditional_mean	-0.075**	(0.028)	0.131	(0.080)	-0.252	(0.176)
informal	0.002	(0.007)	0.044	(0.024)	0.049	(0.041)
informal_mean	-0.008	(0.045)	0.318*	(0.126)	0.263	(0.275)
owner	0.009	(0.005)	-0.112***	(0.019)	-0.061	(0.032)
owner_mean	0.023	(0.033)	-0.250**	(0.097)	-0.122	(0.194)
pipe water	0.005	(0.007)	-0.039*	(0.019)	-0.010	(0.037)
pipe water_mean	-0.007	(0.020)	-0.034	(0.052)	-0.068	(0.113)
flush toilet	-0.038***	(0.007)	0.232***	(0.021)	0.029	(0.043)

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Variable	Probit		The second-stage OLS		2PM	
	Marginal effect	Delta-method Std. Err.	Marginal effect	Std. Err.	Marginal effect	Bootstrap Std. Err.
flush toilet_mean	0.003	(0.022)	-0.087	(0.063)	-0.065	(0.154)
winter	0.002	(0.004)	-0.004	(0.013)	0.004	(0.025)
winter_mean	0.017	(0.018)	0.038	(0.047)	0.119	(0.107)
summer	-0.001	(0.004)	-0.010	(0.013)	-0.016	(0.023)
summer_mean	-0.019	(0.016)	-0.104*	(0.044)	-0.196*	(0.097)
ln(*age*)	0.004	(0.005)	0.009	(0.016)	0.029	(0.031)
ln(*age_mean*)	-0.047	(0.047)	-0.098	(0.124)	-0.327	(0.285)
female	0.000	(0.004)	-0.032**	(0.011)	-0.030	(0.020)
female_mean	-0.071*	(0.031)	-0.163	(0.088)	-0.511**	(0.190)
Coloured	-0.011	(0.007)	0.234***	(0.023)	0.165***	(0.039)
Coloured_mean	0.021	(0.026)	-0.247**	(0.077)	-0.129	(0.158)
Indian/Asian	0.021	(0.018)	0.487***	(0.045)	0.562***	(0.111)
Indian/Asian_mean	0.021	(0.081)	0.227	(0.237)	0.321	(0.512)
White	-0.010	(0.008)	0.511***	(0.028)	0.430***	(0.050)
White_mean	0.161**	(0.059)	-0.039	(0.155)	0.769*	(0.350)
primary	-0.004	(0.007)	-0.006	(0.018)	-0.027	(0.037)
primary_mean	-0.084	(0.048)	0.173	(0.122)	-0.254	(0.300)
secondary	-0.009	(0.007)	-0.010	(0.019)	-0.053	(0.038)
second_mean	-0.132**	(0.046)	-0.048	(0.121)	-0.704*	(0.289)
matric	-0.004	(0.007)	0.002	(0.020)	-0.016	(0.041)
matric_mean	-0.111*	(0.047)	0.002	(0.123)	-0.552*	(0.272)
matric plus	-0.020*	(0.009)	0.027	(0.029)	-0.073	(0.055)
matric plus_mean	-0.075	(0.090)	0.215	(0.233)	-0.170	(0.465)
radio	0.008*	(0.003)	0.003	(0.010)	0.045*	(0.020)
radio_mean	0.052*	(0.021)	-0.173**	(0.060)	0.095	(0.134)
stereo/HiFi	0.004	(0.004)	0.052***	(0.012)	0.068**	(0.022)
stereo/HiFi_mean	0.125***	(0.029)	0.192*	(0.075)	0.807***	(0.181)
TV	0.014**	(0.005)	0.090***	(0.018)	0.153***	(0.032)
TV_mean	-0.231***	(0.054)	0.430**	(0.138)	-0.747*	(0.316)
DVD	0.005	(0.004)	0.056***	(0.013)	0.076**	(0.024)
DVD_mean	-0.060	(0.045)	-0.139	(0.118)	-0.430	(0.271)
refrigerator	0.020***	(0.005)	0.172***	(0.017)	0.263***	(0.030)
refrigerator_mean	0.018	(0.045)	-0.150	(0.126)	-0.052	(0.270)
stove	0.021***	(0.006)	0.107***	(0.019)	0.207***	(0.034)
stove_mean	0.047	(0.039)	-0.110	(0.102)	0.129	(0.233)
microwave	0.005	(0.005)	0.119***	(0.014)	0.138***	(0.026)
microwave_mean	0.018	(0.042)	0.366**	(0.113)	0.435	(0.266)
washing machine	0.003	(0.005)	0.115***	(0.015)	0.123***	(0.028)
washing machine_mean	-0.028	(0.040)	0.012	(0.110)	-0.127	(0.236)

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Variable	Probit		The second-stage OLS		2PM	
	Marginal effect	Delta-method Std. Err.	Marginal effect	Std. Err.	Marginal effect	Bootstrap Std. Err.
computer	-0.010	(0.006)	0.148***	(0.018)	0.090**	(0.034)
computer_mean	0.177*	(0.071)	-0.170	(0.180)	0.722	(0.400)
camera	0.002	(0.007)	0.065**	(0.021)	0.072	(0.039)
camera_mean	-0.128	(0.068)	-0.290	(0.199)	-0.915	(0.471)
cellphone	0.002	(0.006)	0.092***	(0.019)	0.098**	(0.033)
cellphone_mean	0.141**	(0.047)	0.181	(0.132)	0.875**	(0.291)
telephone	-0.002	(0.006)	0.124***	(0.019)	0.109**	(0.034)
telephone_mean	-0.121*	(0.051)	0.109	(0.136)	-0.503	(0.321)
DStv	0.002	(0.005)	0.139***	(0.015)	0.144***	(0.030)
DStv_mean	0.079*	(0.037)	-0.140	(0.098)	0.264	(0.208)
internet	-0.014	(0.008)	0.073**	(0.028)	-0.000	(0.047)
internet_mean	-0.211	(0.113)	-0.497	(0.293)	-1.524*	(0.636)
power tool	0.003	(0.006)	0.069***	(0.018)	0.080*	(0.035)
power tool_mean	-0.054	(0.047)	-0.001	(0.129)	-0.269	(0.306)
Western Cape	0.040*	(0.016)	-0.023	(0.047)	0.181	(0.093)
Eastern Cape	0.050***	(0.013)	-0.264***	(0.039)	-0.001	(0.078)
Northern Cape	0.028	(0.014)	0.024	(0.045)	0.164	(0.084)
Free State	0.031*	(0.013)	-0.210***	(0.034)	-0.043	(0.076)
KZN	0.062***	(0.015)	0.143***	(0.040)	0.445***	(0.089)
North West	0.061***	(0.011)	-0.107**	(0.031)	0.206**	(0.064)
Mpumalanga	0.027*	(0.011)	-0.036	(0.031)	0.100	(0.063)
Limpopo	0.063***	(0.014)	-0.130***	(0.039)	0.192*	(0.089)
constant			1.580*	(0.627)		
R^2			0.5759			
Observation	16 851		15 903		16 851	

_mean denotes the mean value of corresponding variable. Dependent variable is $\ln Y$ for the second-stage OLS. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A.1: Comparison of the variable means.

Variable	Retained sample (N=16 851)			Dropped sample (N=8 164)		
	Observation	Mean	Std. Dev	Observation	Mean	Std. Dev
Y	16 851	225.352	335.153	8 164	54.105	188.873
I	16 851	8 396.801	13 501.620	8 164	7 531.617	13 653.720
p	16 851	80.506	11.144	8 164	79.805	12.193
nonlinear	16 851	0.318	0.466	8 164	0.468	0.499
fbe	16 851	0.283	0.450	5 209	0.171	0.377
Y_{gas}	16 851	2.74	56.59	8 164	4.379	48.868
Y_{liquid}	16 851	7.83	63.88	8 164	16.363	64.229
Y_{solid}	16 851	5.14	43.35	8 164	7.848	36.174
d_{gas}	16 851	0.01	0.10	8 164	0.013	0.114
d_{liquid}	16 851	0.08	0.28	8 164	0.188	0.390
d_{solid}	16 851	0.08	0.27	8 164	0.185	0.388
hsize	16 851	4.037	2.349	8 164	3.184	2.247
room	16 851	4.451	2.074	8 164	3.251	2.226
urban	16 851	0.628	0.483	8 164	0.676	0.468
formal	16 851	0.875	0.331	8 027	0.730	0.444
traditional	16 851	0.070	0.255	8 027	0.131	0.338
informal	16 851	0.055	0.228	8 027	0.139	0.346
owner	16 851	0.896	0.306	8 160	0.492	0.500
pipe water	16 851	0.867	0.340	8 144	0.788	0.409
flush toilet	16 851	0.595	0.491	8 059	0.612	0.487
winter	16 851	0.245	0.430	8 164	0.238	0.426
summer	16 851	0.275	0.446	8 164	0.249	0.432
age	16 851	48.390	15.913	8 164	47.703	15.782
female	16 851	0.459	0.498	8 164	0.387	0.487
African/Black	16 851	0.797	0.402	8 164	0.785	0.411
Coloured	16 851	0.115	0.319	8 164	0.093	0.291
Indian/Asian	16 851	0.015	0.120	8 164	0.026	0.160
White	16 851	0.074	0.261	8 164	0.096	0.294
no schooling	16 851	0.125	0.331	7 972	0.111	0.314
primary	16 851	0.271	0.444	7 972	0.264	0.441
secondary	16 851	0.329	0.470	7 972	0.331	0.470
matric	16 851	0.227	0.419	7 972	0.240	0.427
matric plus	16 851	0.048	0.213	7 972	0.054	0.226
radio	16 851	0.546	0.498	8 112	0.538	0.499
stereo/HiFi	16 851	0.301	0.459	8 029	0.204	0.403
TV	16 851	0.854	0.353	8 123	0.606	0.489
DVD	16 851	0.653	0.476	8 111	0.464	0.499
refrigerator	16 851	0.823	0.382	8 114	0.524	0.499
stove	16 851	0.908	0.289	8 116	0.811	0.392
microwave	16 851	0.479	0.500	8 102	0.327	0.469
washing machine	16 851	0.349	0.477	8 115	0.235	0.424
computer	16 851	0.166	0.372	8 081	0.147	0.354
camera	16 851	0.115	0.319	8 057	0.117	0.321
cellphone	16 851	0.907	0.290	8 091	0.871	0.335
telephone	16 851	0.142	0.349	8 083	0.097	0.296
DStv	16 851	0.229	0.420	8 086	0.158	0.364
internet	16 851	0.060	0.238	8 092	0.059	0.236
power tool	16 851	0.131	0.337	8 051	0.092	0.288
Western Cape	16 851	0.128	0.334	8 164	0.097	0.296
Eastern Cape	16 851	0.128	0.334	8 164	0.138	0.345
Northern Cape	16 851	0.051	0.220	8 164	0.041	0.198
Free State	16 851	0.097	0.296	8 164	0.063	0.243
KwaZulu-Natal	16 851	0.127	0.333	8 164	0.176	0.381
North West	16 851	0.112	0.315	8 164	0.075	0.264
Gauteng	16 851	0.115	0.319	8 164	0.232	0.422
Mpumalanga	16 851	0.093	0.290	8 164	0.088	0.284
Limpopo	16 851	0.150	0.357	8 164	0.088	0.284