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Temporal analysis of electricity consumption for prepaid metered low- and high-income households in Soweto, South Africa

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This study explores the temporal trend in electricity consumption since the introduction of prepaid metres in low-income households of Soweto and compares the findings with high-income households. Monthly electricity consumption data (over 96 months: 2007–2014) for 4427 households in Soweto, for both low- and high-income households, was collected from Eskom. Using a simple linear model to analyse consumption trends in low-income households, we ascertained that electricity consumption has decreased by 48% since the inception of prepaid metres. Nonetheless, it is noted that 60% of household incomes are spent on electricity bills, which is way above the threshold set for energy poverty. Comparatively, high-income households consume less electricity than low-income households do. Overall, the prepaid metre programme is producing expected results for Eskom but remains a challenge for low-income households, which are still entrenched in energy poverty. We call for an energy policy that is tailored for each income groups and the formulation of laws and policies to protect the energy vulnerable households.

Keywords: electricity consumption, high-income household, low-income household, prepaid electricity meter, socio-economic

Introduction

Household electricity debt continues to plague South Africa's electricity supplying utility – Eskom – as only 16% of households pay for the electricity service Eskom provides (Timeslive 2015). The consequence of non-payment on public utilities is enormous. First, it is an important constraint to the provision of electricity services (Szabo and Ujhelyi 2014). Second, the shortage in revenue that comes with non-payment ultimately results in maintenance backlogs, system deterioration, inability to purchase fuel to operate the generating units, and the deterioration of the economy (World Bank 1999). Third, studies have found that there is a correlation between non-payment and expenditure ratios: households with increasing electricity consumption (as a percentage of total household expenditure) are more likely to not pay regularly for their consumption (World Bank 1999; Lampietti, Banerjee, and Branczik 2007).

Different countries experience the problem of non-payment differently and deal with it in different ways. In 2003, the South African government persuaded Eskom to erase electricity household debt of R1.4 billion (US $1.2 million), under the Free Basic Electricity (FBE) policy (Styan 2015). Then, the government took some measures to avoid further debt in the future. These measures included the introduction of prepaid meters and a free monthly allocation of electricity incentive (50 kWh) for all indigent households that agreed to have prepaid meters installed (DME 2003). As opposed to the expected outcome of these policies (e.g. Free Basic Electricity, free 50 kWh electricity consumption), household debt increased to R13.6 billion (US$1.14 billion), of which Soweto township alone owed R8.6 billion (US $7.2 million), 60% of the total amount due to massive electricity non-payment (Styan 2015). As a result, Eskom has resorted to intensifying its efforts to deploy prepaid household meters in the township.

In 2007, the first official prepaid electricity-meter pilot project was undertaken in a small region of Soweto known as *Chiawelo*. To date, more than 45% of low-income households in Soweto are prepaid metered; the target is that all households be connected to this model of payment by 2020 (City Press 2016). While households have protested and rejected the prepaid meter technology, Eskom has persistently echoed that the technology stands to benefit rather than harm households (Ruiters 2007; Makonese, Kimemia, and Annergarn 2012; Chinomona and Sandada 2014; City Press 2015; Jack and Smith 2015, 2016; Press Reader 2015; Timeslive 2015; SABC 2016; IOL 2017) and this view is supported by several studies across various geographic regions where significant decreases in electricity consumption were reported (Darby 2006; Fischer 2008; Faruqui, Sergici, and Sharif 2010; Gans, Alberini, and Longo 2013; Qui and Xing 2015). For example, Faruqui, Sergici, and Sharif (2010) found that in North America the prepaid-metre technology reduced electricity consumption by 7% whereas in Northern Ireland, Gans, Alberini, and Longo (2013) reported a decrease of 11–17%. Similarly, Martin (2014) reported that households using prepaid electricity metres in Kentucky, USA, have reduced their electricity consumption by 11%. A study conducted in Canada noted that 25% of the sampled households utilized 20% less electricity with prepaid-metre technology (Casarin and Nicollier 2009). This decrease is the result of direct feedback on electricity consumption provided by prepaid meters, thus enabling consumers to monitor their electricity consumption.

Although Qui and Xing (2015) confirmed the reduction pattern of electricity consumption in Arizona,

USA, due to prepaid metres, they also called for caution in generalizing this trend as they pointed out that socio-economic factors matter in electricity consumption. Specifically, they indicated that low-income households tend to experience more electricity reductions than high-income households, suggesting a context-dependent effect of prepaid meters on electricity consumption. Based on Qui and Xing's (2015) finding, we therefore hypothesized that low-income households in Soweto would also consume more electricity than high-income households due to the differences in the types of appliances used in both income groups. This is in line with several other studies that questioned whether prepaid meters are truly beneficial to low-income households (Colton 2001; Ruiters 2007; van Heusden 2010; O'Sullivan, Howden-Chapman, and Fougere 2011; Hittinger et al. 2012; Makonese, Kimemia, and Annergarn 2012; Malama et al. 2014). These studies have alluded to the fact that prepaid electricity meters have the potential of entrenching energy poverty, especially among energy-vulnerable households. Energy vulnerability precedes energy poverty. At the vulnerable phase, there is a set of prevailing household conditions or factors that may lead to poverty. An acknowledgement of this phase helps to identify groups of people that may be at risk of being energy-poor in the near future. In expenditure terms, these are households that tend to spend more than 10% of their income to meet their energy-related needs (O'Sullivan, Howden-Chapman, and Fougere 2011; Bouzarovski and Petrova 2015; Ismail and Khembo 2015). Poor household energy efficiency, increasing electricity costs, and overcrowding are identified as other key causal factors in energy poverty (The Guardian 2016).

For example, when, from 1990 to 2008, the price of electricity in New Zealand markedly increased by 71%, this increase led to energy poverty in low-income areas but not in high-income households (O'Sullivan, Howden-Chapman, and Fougere 2011, 2015). The differences in electricity consumption in low- versus high-income households are due to the differences in the nature of dwellings and appliances used (Genjo et al. 2005; Tso and Yau 2007; Druckman and Jackson 2008; Wiesmann et al. 2011; DoE 2012; Bedir, Hasselaar, and Itard 2013; Jones, Fuertes, and Lomas 2015). In such a context, it is not an effective measure to design a 'one-size-fit-all policy' for electricity consumption across all households without taking into consideration socio-economic differences.

The gap the present study fills, and its contribution are as follows. In the context of Soweto, we do not know the consumption patterns over time in low- versus high-income households and how consumption in high-income households compares to consumption in low-income households. The present study provides answers to this gap in the information we have, and, in so doing, contributes knowledge that can inform the prepaid meter programme in Soweto. Specifically, we aim to understand the influence of prepaid meters on electricity consumption in this South Africa's township. Our objectives are threefold: i) to identify the trend of electricity consumption since the introduction of prepaid metre in 2007; ii) to identify the proportion of change in consumption since 2007; and iii) to compare electricity consumption in low- versus high-income households in Soweto township.

Material and method

Study area

The present study was conducted in Soweto, the largest (200.3 km^2) township in South Africa with a population of about 1,271,628 inhabitants (Frith 2017). Within the township, two areas were targeted, namely, Chiawelo and Diepkloof Extension.

Chiawelo is a largely low-income household area of Soweto, established in 1956. Its size is about 1.10 km^2, and was developed to provide cheap accommodation for black workers (specifically Tsonga- and Venda-speaking South Africans) during the apartheid era. Approximately 3841 households are found in Chiawelo (Frith 2017). The household structures have 3–4 small rooms (with each room size of $\sim$ 32 m^2). A significant majority of these households generate money by renting backyard dwellings (e.g. shacks they have constructed). Eskom installed prepaid meters in the area in 2007. The area is still considered one of the socio-economically disadvantaged areas in Soweto.

Diepkloof Extension (DE) is a segment region of Diepkloof sub-township with a surface area of about 1.42 km^2 (Frith 2017). It has about 1564 households. The area developed in the early 1980s and 1990s (Alexander et al. 2013). It was built for middle- to upper-class blacks (wealthier blacks, who were largely professionals employed by the state, but also privately employed professionals) (Marx and Rubin 2008; Alexander et al. 2013). The area is therefore referred to as the 'Rich Man's Acre'; the house structures are bigger and intended as a more exclusive area. Most households in DE are modern and constantly being renovated towards being energy efficient. They are noticeably distinct from houses in the old townships of Soweto, with structures that are more permanent, built with expensive building materials (brick and tiled roofs as opposed to corrugated iron walls and roofs). The houses' physical structure size is estimated to be between 200 and 300 m^2. The area received prepaid meters in 2013. Overall, this is a socio-economically well-off region of Soweto.

Data collection

The electricity consumption data in Chiawelo and DE was acquired from Eskom. The agreement between the utility and the researchers is that the anonymity of each household's data (electricity consumption and cost) is preserved. We maintained this anonymity by not sharing the collected raw data for any household. Prepaid meters were not installed in both Chiawelo and DE at the same time. While the prepaid metre programme was introduced to low-income households in 2007, the programme was introduced to high-income households only in 2016. As a result, data on consumption were not available for similar period. Data on electricity consumption and cost for Chiawelo (low-income households) were collected monthly over 96 months i.e. eight years (2007 to 2014) for 3 841 households whereas data for DE (high-income

households) were collected for 1 564 total households only from June 2016 to February 2017 for the reason indicated above (i.e. prepaid meters were introduced to high-income households in 2016 and data for this income group are available for only 2016 to 2017).

Data analysis

All analyses were done in R (R-Development Core Team 2015). Firstly, we analyzed the trend of electricity consumption over eight years (2007–2014) in low-income households. This analysis was done using a simple linear regression. Secondly, we assessed by how much the electricity consumption had changed in low-income households over the study period (2007–2014) since the introduction of prepaid meters to this income group. This change was calculated as:

$C_{\text{consumption}} = ((C_{2014} - C_{2007})/C_{2007})$; C_{2014} and C_{2007} are the total electricity consumption in 2014 and 2007, respectively.

We then analyzed the trend in monthly electricity consumption over the same period using the analysis of covariance (ANCOVA) with year and month as co-variates. To further understand the monthly patterns of electricity consumption, we ran a one-way ANOVA using consumption as a response variable and month as a predictive variable.

Finally, we compared the consumption patterns between low- and high-income households. Because we have monthly consumption data for only a limited period of time (nine months: June 2016 to February 2017) in high-income households while we have monthly consumption for 96 months in low-income households, we tested the differences in consumption in both income groups by comparing the average monthly consumption in low-income households versus the average monthly consumption in randomly drawn years from 2007 to 2014 in low-income households. This comparison was done as follows. We selected randomly 100 times a year between 2007 and 2014, and calculated the average monthly consumption for each randomly selected year. Then, we calculated the actual monthly average consumption of high-income households over the period of June 2016 to February 2017 and compared this actual average to the average monthly consumption in low-income households of the randomly selected years. The significance of the difference between actual and random consumption was assessed using the 95% confidence interval (CI). For this particular analysis, the consumption data were $\log_{10}$-transformed to meet the normal error distribution.

Results

Our results indicate that electricity consumption in low-income households decreased significantly ($P < 0.001$) over the study period (2007–2014), following the trend $y = -63.78\,x + 129071.94$ ($R^2 = 25.13\%$) (Figure 1). We also found that, since the introduction of prepaid electricity meters, the consumption levels decreased by a monthly average of 48% in low-income households over the study period. The decrease reached its lowest level in 2010 (610–930 kWh) (Figure 2). However, this overall decreasing trend hides some specificities in some months where the consumptions increased significantly in comparison to the average monthly consumption. These months include May ($\beta = 252.94 \pm 122.62$; $P = 0.04$), June ($\beta = 436.82 \pm 118.72$; $P = 0.0004$), July ($\beta = 453.73 \pm 118.72$; $P = 0.0002$) and August ($\beta = 310.69 \pm 118.72$; $P = 0.01$) (Figure 3). Finally, we found that energy consumption in low-income households was significantly higher than consumption in high-income household [(mean consumption in high-income household (log) = 6.28; CI = 6.65–6.76)] (Figure 4). Our model [$y = -63.78\,x + 129071.94$ ($R^2 = 25.13\%$)] shows that the low-income household electricity consumption levels equalled high-income household levels in the year 2015.

Discussion

As a means to reduce the challenge of household electricity non-payment in Soweto, Eskom effected the process of prepaid electricity meter deployment in 2007. This study evaluates the role of the technology, particularly regarding electricity consumption, in low- and high-income households in the township. We firstly assessed the trend in prepaid electricity consumption in low-income households in Soweto. Using a simple linear model, we found that the rate of consumption has decreased by 48% between 2007 and 2014. We acknowledge that the strength of our model is weak (25%), suggesting that 75% of variation in electricity consumption remains unexplained by the linear model. However, our finding is broadly consistent with the general trend reported in several studies across various geographic regions (Canada: 20% decrease, Casarin and Nicollier 2009; North America: 7% decrease, Faruqui, Sergici, and Sharif 2010; Northern Ireland: 11–17% decrease; Gans, Alberini, and Longo 2013; Kentucky: 11% decrease; Martin 2014; Arizona: 12% decrease, Qui and Xing 2015). It is also important to highlight that the decrease reported in our study is much higher (48%) than any other decrease reported elsewhere in relation to the installation of prepaid meters. This is potentially due to the fact that we focused only on electricity consumption in low-income households, whereas other studies analyzed a combined dataset from both low- and high-income households (Qui and Xing 2015).

Our results also reflect that the overall declining trend camouflages some energy consumption specificities in some months. For example, despite the overall decreasing trend, consumption increased significantly in comparison to the average monthly consumption from May to August, with the lowest consumption observed in June 2010. The significant increased consumption in May–August is linked to the winter period in South Africa when the response to the cold weather requires an increase in energy demand to warm houses. Households therefore spend more and become more energy vulnerable during the winter season (Lampietti, Banerjee, and Branczik 2007). The sharp decline in electricity consumption in June 2010 in Soweto's low-income households could be linked to the Soccer World Cup. Soccer in Soweto is almost a religion, and the world cup was an opportunity for people to experience the once-in-a-lifetime opportunity

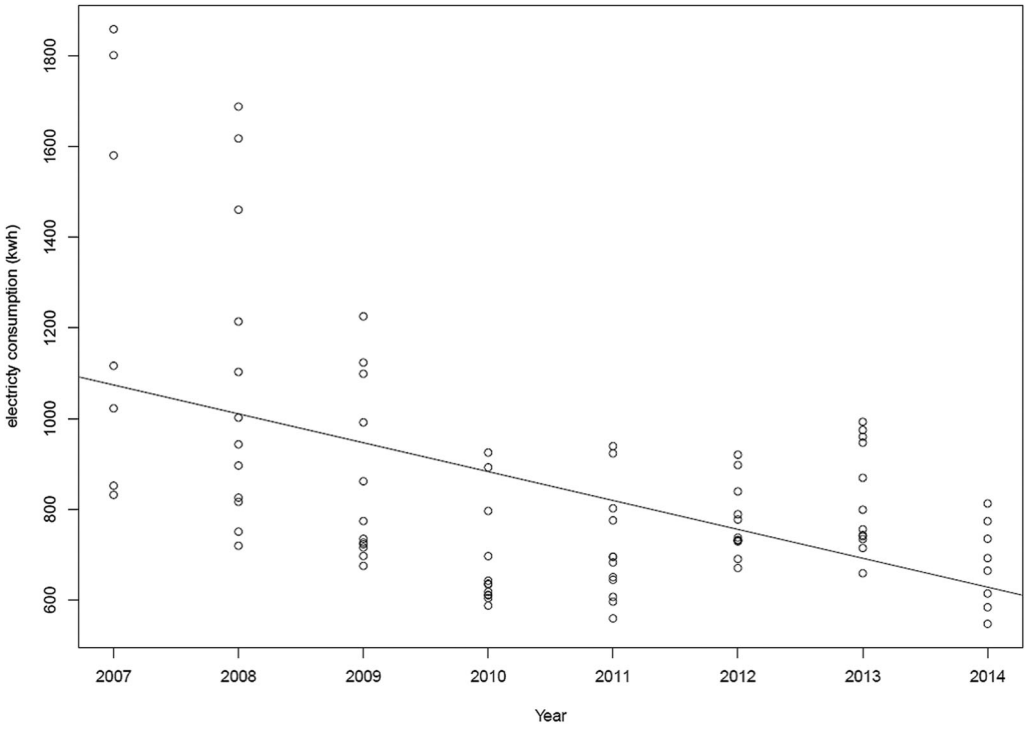

Figure 1: Trend of yearly electricity consumption in low-income households since the introduction of prepaid meters in 2007 (2007–2014).

that the world cup provided. As such, people were mostly outdoors in different stadiums watching the games, or people convened at one single household to watch the games, and consequently the consumption of electricity dropped significantly explaining the lowest June 2010 energy consumption that we observed in our study. This is an illustration of how social events such as the soccer world cup may contribute to energy efficiency in low-income households. However, it is also important to find out if this is true at a national level.

The overall decreasing trend should not mask the socio-economic implications for low-income households. Understanding these socio-economic implications is very important in a policymaking process that takes income level into consideration. For example, each household in Chiawelo – the low-income region in this study – consumed an average

Figure 2: Trend of yearly electricity consumption in low-income households highlighting the monthly patterns.

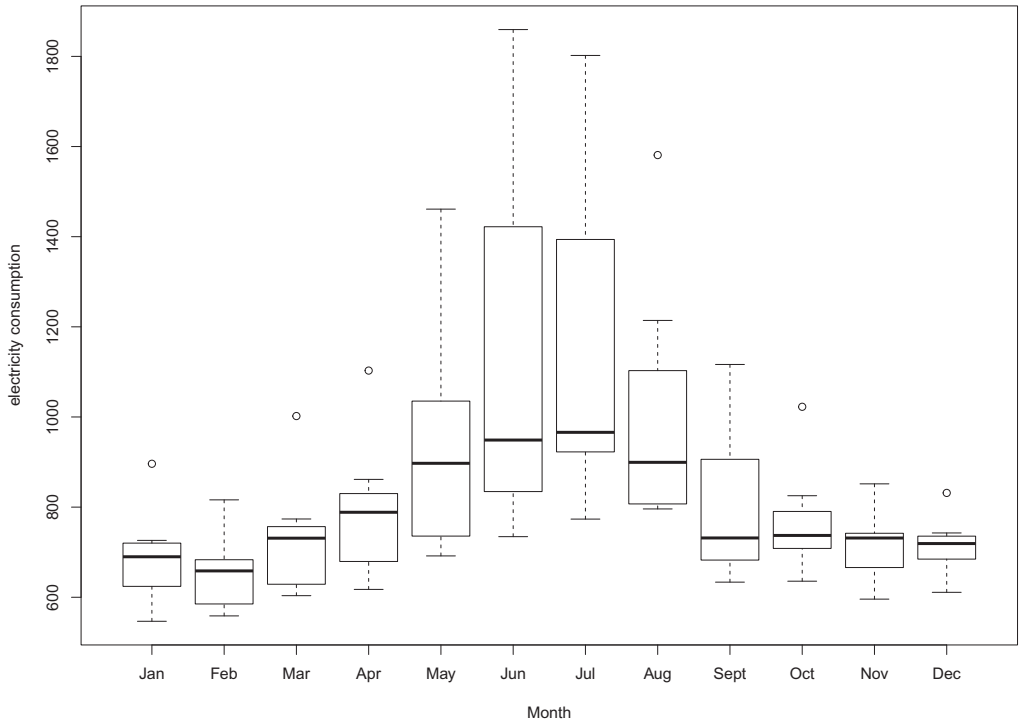

Figure 3: Boxplots depicting the monthly variation in electricity consumption.

of 667.6 kWh in 2014. Assuming the 2014 electricity tariff of R0.98 per kWh, households therefore monthly spent R654.2. By applying the upper-bound poverty line (UBPL) (using the 2015 prices), low-income households have a monthly income of approximately R992 per month (StatsSA 2017), meaning that households spent about 66% of their monthly income just to cover their electricity consumption. This renders households vulnerable to energy poverty, particularly in the context of recent and predicted future increases in electricity tariffs. Consequently, prepaid meters may lead to decreased electricity consumption, but it does not solve the problem of energy poverty in low-income households. This is in support of the previous views that prepaid meters may entrench socio-economic marginalization and electricity inequality (Colton 2001; Ruiters 2007; van Heusden 2010), given that spending up to 46% of households income (in winter) only on electricity consumption would have severe consequence on many other sectors of the household lives including education, food, health, clothing, transport, etc. This is in contrast to an early claim that prepaid meters improve social welfare (Casarin and Nicollier 2009).

To alleviate the weight of electricity consumption, the incentive measures put in place by the government include free monthly consumption of 50 kWh. This is clearly not enough in light of the amount spent to cover electricity bills despite the remarkable decrease in consumption. The current energy or electricity policy landscape for households is poor and offers only limited energy security to the poor. It does not offer energy vulnerable or impoverished households protection. The FBE policy is currently the main policy that provides an incentive for poor households. We strongly argue that it lacks relevance and needs to be evaluated and updated according to the socio-economic realities faced by indigent households.

Similar evidence of energy poverty has also been reported in many other countries. In Zambia, for example, Malama et al. (2014) reported that low-income households suffer from prepaid metre disconnections because of high and unaffordable prices (Malama et al. 2014). In response, low-income households shift from using electricity to alternative energy sources such as wood or coal-burning stoves, paraffin fuelled heaters, gas heaters, hot water bottles and usage of bed-blankets. This is an important finding for policymakers because it carries indicators closely associated with fuel or energy poverty – that is the inability of households to acquire adequate household electricity for safe and healthy indoor temperatures (O'Sullivan et al. 2013). Furthermore, according to Ismail and Khembo (2015), the energy poverty expenditure line is estimated to be 10–15% of income. Low-income households were found to spend about 66% of their income on electricity. This is an apparent indicator of socio-economic marginalization of poor households. Higher expenditure on electricity among low-income households means they become more energy vulnerable (World Bank 1999; Lampietti, Banerjee, and Branczik 2007). Again, with increasing unemployment and electricity tariffs (by 400% in the past decade) in Soweto, the ill effect of prepaid meters on energy poverty needs to be thoroughly studied. There is a need for policymakers to re-assess and monitor the prepaid meter programme, and, as Colton (2001) advised, establish mechanisms (e.g. laws) to protect the fuel or energy vulnerable and impoverished households.

How does electricity consumption in low-income households compare to the consumption in high-income households? Our analysis showed that low-income households consume significantly more electricity than high-income households despite the trend towards a decreased

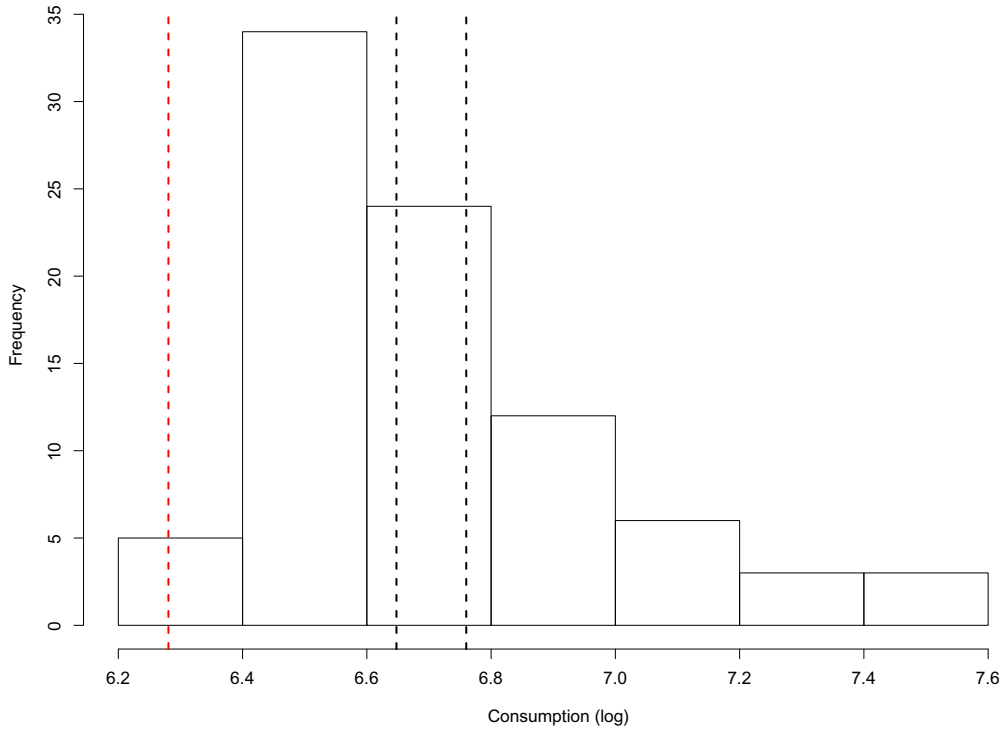

Figure 4: Comparison of electricity consumption between low- and high-income households from 2007 to 2014. The histogram indicates the average distribution of monthly electricity consumption in randomly selected years in low-income households between 2007 and 2014. The bold dotted black lines indicate the confidence interval for the random consumption. The bold dotted line indicates the actual monthly average consumption of high-income households. The dotted black and vertical lines mean: 1) Black dotted line – confidence interval for consumption in low-income household. 2) Vertical dotted line – average monthly consumption of high-income households.

consumption in low-income households over several years. This may largely be attributable to factors unique to low-income households, for instance their continued dependence on old energy inefficient appliances and provision of space to rent backyard rooms or shacks on their premises (Makonese, Kimemia, and Annergarn 2012) – as compared to energy efficient buildings and appliances used by high-income households. A study conducted by Parker (2003) reported that because of *inter alia* less efficient appliances, older homes consumed greater electrical energy for space heating and cooling. Furthermore, low-income households are also characterized by backyard dwellings that are rented out, thus contributing to additional electricity consumption.

In contrast, high-income households comprise in general only two employed persons per household (StatsSA 2011). This household category receives an annual income of more than R307 201 (about R26 000 per month). This household is characterized by a dwelling solely dependent on electricity and gas as the main sources of energy for cooking, lighting and heating. Electricity appliances found in households in this income group include a radio, television, computer, refrigerator and cell phone. This household category is considered broadly energy efficient and can afford energy efficient electrical appliances, thus justifying the lower electricity consumption in comparison to low-income households. Several other factors not explicitly explored in the present study may also account for the differences observed. These include household expenditure patterns, education level, household and dwelling size, location of the household, all factors that have been recently identified as determinants of energy poverty in South Africa (Ismail and Khembo 2015). Based on our simple linear model, we identified that low-income households may have reached the same consumption level as high-income households since 2015. Unfortunately, we do not yet have a consumption dataset beyond 2014 to confirm this prediction, which also precludes us from verifying whether the general decreasing trend since 2007 has been maintained beyond 2014.

Conclusion

South Africa's Energy White Paper clearly indicated that 'energy security for low-income households can help reduce poverty, increase livelihoods and improve living standards' (DME 1998). Our trend analysis reveals that low-income households are consuming lesser electricity over time owing to prepaid meters, and this is positive development in support of the prepaid meter policy established since 2007. However, as more than 60% of the income in indigent households is spent on electricity consumption, way above the energy poverty expenditure threshold, estimated to be 10–15% (Ismail and Khembo 2015). We recommend to policymakers to review and monitor the prepaid metre programme and to formulate tools (e.g. laws) to protect such energy vulnerable and impoverished households. Furthermore, we conclude that despite this decrease in energy consumption, low-income households continue to consume more electricity

than high-income households. We therefore propose that in the midst of the current electricity crisis in South Africa, there is an urgent need for the government to subsidize the installation of renewable energy technologies in low-income households. We also recommend that since the FBE policy is currently the main document providing an incentive to poor households, this policy needs to be evaluated and updated according to the socio-economic and energy poverty realities facing the majority of low-income households in Soweto.

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Disclosure statement

No potential conflict of interest was reported by the authors.

References

Alexander, P., C. Ceruti, K. Motseke, M. Phadi, and K. Wale. 2013. *Class in Soweto*. Durban: University of KwaZulu-Natal Press.

Bedir, M., E. Hasselaar, and L. Itard. 2013. "Determinants of Electricity Consumption in Dutch Dwellings." *Energy and Buildings* 58: 194–207.

Bouzarovski, S., and S. Petrova. 2015. "A Global Perspective on Domestic Energy Deprivation: Overcoming the Energy Poverty–Fuel Poverty Binary." *Energy Research & Social Science* 10: 31–40.

Casarin, A. A., and L. Nicollier. 2009. Prepaid Meters in Electricity. A Cost-Benefit Analysis. Working Paper Series IAE.

Chinomona, R., and M. Sandada. 2014. "Customers' Perceptions on Eskom's Pre-Paid Billing System and the Effects on Their Satisfaction and Trust." *Mediterranean Journal of Social Sciences* 9: 119–126.

City Press. 2015. Soweto Residents Want Flat Electricity Rate But Use Energy Hungry Appliances. Accessed December 13, 2017. http://city-press.news24.com/News/Soweto-residents-want-flat-electricity-rate-but-use-energy-hungry-appliances-20150510.

City Press. 2016. Eskom Holds Thumbs Soweto Will Accept its New Smart Meters. Accessed September 20, 2017. http://city-press.news24.com/News/eskom-holds-thumbs-soweto-will-accept-its-new-smart-meters-20160430.

Colton, D. R. 2001. "Prepayment Utility Meters, Affordable Home Energy, and the Low Income Utility Consumer." *Journal of Affordable Housing and Development Law* 3: 285–305.

Darby, S. 2006. The Effectiveness of Feedback on Energy Consumption: A Review for Defra of the Literature on Metering, Billing and Direct Displays. Page: 1–21.

DME (Department of Minerals and Energy). 1998. White Paper on the Energy Policy of the Republic of South Africa. Available Online: http://www.energy.gov.za/files/policies/whitepaper_energypolicy_1998.pdf.

DME (Department of Minerals and Energy). 2003. Electricity Basic Services Support Tariff (Free Basic Electricity) Policy. Accessed March 12, 2018. http://www.energy.gov.za/files/policies/Free20Basic20Electricity20Policy202003.pdf.

DoE (Department of Energy). 2012. A Survey of Energyrelated Behaviour and Perceptions in South Africa: The Residential Sector. Accessed at http://www.energy.gov.za/files/media/Pub/Survey%20of%20Energy%20related%20behaviour%20and%20perception%20in%20SA%20-%20Residential%20Sector%20-%202012.pdf

Druckman, A., and T. Jackson. 2008. "Household Energy Consumption in the UK: A Highly Geographically and Socio-Economically Disaggregated Model." *Energy Policy* 36: 3177–3192.

Faruqui, A., S. Sergici, and A. Sharif. 2010. "The Impact of Informational Feedback on Energy Consumption—A Survey of the Experimental Evidence." *Energy* 35: 1598–1608.

Fischer, C. 2008. "Feedback on Household Electricity Consumption: A Tool for Saving Energy?" *Energy Efficiency* 1: 79–104.

Frith, A. 2017. Population Statistics. Accessed March 12, 2018. https://census2011.adrianfrith.com/place/798026.

Gans, W., A. Alberini, and A. Longo. 2013. "Smart Meter Devices and the Effect of Feedback on Residential Electricity Consumption: Evidence from a Natural Experiment in Northern Ireland." *Energy Economics* 36: 729–743.

Genjo, K., S.-i. Tanabe, S.-i. Matsumoto, K.-i. Hasegawa, and H. Yoshino. 2005. "Relationship Between Possession of Electric Appliances and Electricity for Lighting and Others in Japanese Households." *Energy and Buildings* 37: 259–272.

Hittinger, E., A. Kimberley, I. Mullins, and L. Azevedo. 2012. "Electricity Consumption and Energy Savings Potential of Video Game Consoles in the United States." *Energy Efficiency*, doi:10.1007/s12053-012-9152-z.

IOL. 2017. Chiawelo Residents Stick to Demands. Accessed September 19, 2017. https://www.iol.co.za/news/south-africa/gauteng/chiawelo-residents-stick-to-demands-1094881.

Ismail, Z., and P. Khembo. 2015. "Determinants of Energy Poverty in South Africa." *Journal of Energy in Southern Africa* 3: 66–78.

Jack, B. K., and G. Smith. 2015. Pay as You Go: Pre-paid Metering and Electricity Expenditure in South Africa. Accessed November 15, 2016. https://sites.tufts.edu/kjack/files/2015/08/Jack_manuscript7.pdf.

Jack, B. K., and G. Smith. 2016. Charging Ahead: Prepaid Electctricity Metering in South Africa. NBER Working Paper Series.

Jones, R. V., A. Fuertes, and K. J. Lomas. 2015. "The Socio-economic, Dwelling and Appliance Related Factors Affecting Electricity Consumption in Domestic Buildings." *Renewable and Sustainable Energy Reviews* 43: 901–917.

Lampietti, J. A., S. G. Banerjee, and A. Branczik. 2007. People and Power Electricity Sector Reforms and the Poor in Europe and Central Asia. https://openknowledge.worldbank.org/handle/10986/7175.

Makonese, T., D. K. Kimemia, and H. J. Annergarn. 2012. Assessment of Free Basic Electricity and Use of Pre-paid Meters in South Africa. Accessed October 13, 2016. http://conferences.ufs.ac.za/dl/Userfiles/Documents/00000/577_eng.pdf.

Malama, A., P. Mudenda, A. Ng'ombe, L. Makashini, and H. Abanda. 2014. "The Effects of the Introduction of Prepayment Meters on the Energy Usage Behaviour of Different Housing Consumer Groups in Kitwe, Zambia." *AIMS Energy* 2: 237–259.

Martin, M. W. 2014. Pay As You Go Electricity: The Impact of Prepay Programmes on Electricity Consumption. Theses and Dissertations – Agricultural Economics. p. 29. Accessed October 25, 2016. http://uknowledge.uky.edu/agecon_etds/29.

Marx, C., and M. Rubin. 2008. 'Divisible Spaces': Land Biographies in Diepkloof, Thokoza and Doornfontein, Gauteng. A final draft report prepared for Urban LandMark.

O'Sullivan, K. C., P. L. Howden-Chapman, and G. Fougere. 2011. "Making the Connection: The Relationship Between Fuel Poverty, Electricity Disconnection, and Prepayment Metering." *Energy Policy* 39: 733–741.

O'Sullivan, K. C., P. L. Howden-Chapman, and G. M. Fougere. 2015. "Fuel Poverty, Policy, and Equity in New Zealand:

The Promise of Prepayment Metering." *Energy Research & Social Science* 7: 99–107.

O'Sullivan, K. C., P. L. Howden-Chapman, G. M. Fougere, S. Hales, and J. Stanley. 2013. "Empowered? Examining Self-disconnection in a Postal Survey of Electricity Prepayment Meter Consumers in New Zealand." *Energy Policy* 52: 277–287.

Parker, D. S. 2003. "Research Highlights from a Large Scale Residential Monitoring Study in a Hot Climate." *Energy and Buildings* 35: 863–876.

Press Reader. 2015. Why Sowetan's Won't Pay. Accessed September 19, 2017. https://www.pressreader.com/south-africa/sowetan/20150518/281599534080349.

Qui, L., and B. Xing. 2015. Pre-paid Electricity Plan and Electricity Consumption Behaviour. Accessed August, 18, 2017. http://cmepr.gmu.edu/wp-content/uploads/2014/01/Qiu_pre-paid-pricing_0202.pdf.

R Development Core Team. 2015. *R: A Language and Environment for Statistical Computing*. Vienna: R Foundation for Statistical Computing.

Ruiters, G. 2007. Free Basic Electricity in South Africa: A Strategy for Helping People or Containing the Poor?

SABC (South African Broadcasting Corporation). 2016. 40 000 Smart-Prepaid Metering Systems Installed in Soweto. Accessed February 20, 2017. http://www.sabc.co.za/news/a/778df0804c949ca0b355bfa10755317a/40-000-Smart-Prepaid-metering-systems-installed-in-Soweto.

StatsSA (Statistics South Africa). 2011. Income Dynamics and Poverty Status of Households in South Africa. Accessed September 21, 2017. http://www.statssa.gov.za/publications/Report-03-10-10/Report-03-10-102014.pdf.

StatsSA (Statistics South Africa). 2017. Poverty on the Rise in South Africa. Accessed March 13, 2018. http://www.statssa.gov.za/?p=10334.

Styan, J. B. 2015. *Blackout: The Eskom Crisis*. Johannesburg & Cape Town: Jonathan Ball Publishers.

Szabo, A., and G. Ujhelyi. 2014. Can information Reduce Non-payment for Public Utilities? Experimental Evidence from South Africa. ftp://ftp.repec.org/opt/ReDIF/RePEc/hou/wpaper/2014-114-31.pdf

The Guardian. 2016. The Three Housing Problems that Most Affect Your Health. https://www.theguardian.com/society-professionals/2014/aug/08/housing-problems-affect-health.

Timeslive. 2015. Soweto Shrugs off R4 Billion Eskom Bill. Accessed February 14, 2017. http://www.timeslive.co.za/local/2015/02/03/Soweto-shrugs-off-R4-billion-Eskom-bill.

Tso, G. K. F., and K. K. W. Yau. 2007. "Predicting Electricity Energy Consumption: A Comparison of Regression Analysis, Decision Tree and Neural Networks." *Energy* 32: 1761–1768.

van Heusden, P. 2010. Discipline and the New 'Logic of Delivery': Prepaid Electricity in South Africa and Beyond.

Wiesmann, D., I. Lima Azevedo, P. Ferrão, and J. E. Fernández. 2011. "Residential Electricity Consumption in Portugal: Findings from Top-down and Bottom-up Models." *Energy Policy* 39: 2772–2779.

World Bank. 1999. Impact of Power Sector Reform on the Poor; A Review of Issues and the Literature. https://openknowledge.worldbank.org/bitstream/handle/10986/20317/multi_page.pdf;sequence=1.