Internal Migration and Energy Poverty in South Africa*

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Abstract

Despite recent progress, energy poverty remains pervasive in Sub-Saharan Africa (SSA). This challenge is generally more severe in rural areas. However, rapid urbanization adds on a significant challenge to often under-capacitated urban local authorities that struggle to provide services to new urban dwellers. In the case of South Africa and other SSA countries, this has resulted in a proliferation of under-serviced informal urban settlements on the urban periphery, where a lack of energy access is compounded with a lack of access to other services and job opportunities to result in sites of concentrated and multidimensional deprivation. In this paper, we present the first analysis of the relationship between rural-urban migration and energy poverty in South Africa, and to our knowledge in Africa, using a nationally representative panel dataset. Using a difference in differences approach, we track energy poverty changes for both migrants and non-migrants over a 10-year period. We find that on average, moving to urban areas results in reductions in energy poverty for migrants themselves, with especially dramatic reductions in the use of traditional cooking fuels. However, roughly one in five new urban arrivals move into informal shack dwellings where the gains from migration are negligible from an energy poverty perspective given the rapid increase in grid access and access to electrical appliances taking place in South African rural areas.

Keywords: Electricity; Poverty; Migration; Urbanization; Africa; Panel Data

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1 Introduction

Many large-scale societal transitions such as the one required to bring about an end to energy poverty[1] in developing regions have historically been associated with urbanization (Bertinelli & Black, 2004; Bloom, Canning, & Fink, 2008). The productivity gains associated with the density and connectivity of urban areas means that urban areas have the potential to transform poverty outcomes (and by extension energy access) in African economies (Collier & Venables, 2016). The per-unit fixed costs of energy-related infrastructure fall as the density of connections increases.

However, rapid urbanization also poses a significant challenge to often under-capacitated local authorities that struggle to provide services to new urban dwellers (Bos, Chaplin, & Mamun, 2018; Turok & Borel-Saladin, 2014). In the case of South Africa and other Sub-Saharan African (SSA) countries, this has resulted in a proliferation of under-serviced informal settlements[2] on the urban periphery where a lack of energy access is compounded with a lack of access to other services and job opportunities to result in sites of concentrated and multidimensional deprivation (De Swardt, Puoane, Chopra, & Du Toit, 2005; Mushongera, Zikhali, & Ngwenya, 2017). At the same time, new household formation is likely to be faster in urban than rural areas, which can present an additional challenge for urban energy provision (Harris, Collinson, & Wittenberg, 2017). As such, it is not immediately clear that rural-urban migration results in large reductions in energy poverty for migrants moving from established rural households to households in poorly serviced informal settlements.

The motivation for a focus on rural-urban migration and the energy transition stems from various reasons. Firstly, access to modern energy services – which include cooking, lighting,

[1]Energy poverty is "the state of being deprived of certain energy services or not being able to use them in a healthy, convenient, and efficient manner, resulting in a level of energy consumption that is insufficient to support social and economic development. Although energy poverty can be measured using binary indicators (by specifying a minimum package of energy services or minimum amount of energy use), it is in reality a continuous variable encompassing deprivation on a range of energy services" (Bhatia & Angelou, 2015).

[2]In South Africa, in 2014, 23% of the urban population was living in slums (56% in Sub-Saharan Africa) (Source: United Nations Human Settlement Programme (UN-Habitat), Global Urban Indicators Database 2015).

heating, communication – contributes positively to quality of life and livelihoods. Energy access has the potential to spur numerous positive spillovers into other areas, including incomes (Jeuland et al., 2020; Thomas, Harish, Kennedy, & Urpelainen, 2020), women's empowerment (Grogan, 2016; Das et al., 2020), education (Bonan, Pareglio, & Tavoni, 2017) household satisfaction with energy use (Mahajan, Harish, & Urpelainen, 2020) and basic appliance ownership (Thomas et al., 2020). These positive spillovers have led energy access to being termed a 'golden thread' connecting various development outcomes (Jeuland et al., 2020).

In addition, household air pollution due to cooking with solid fuels is also of particular concern in South Africa due to the high prevalence of tuberculosis, which constitutes a major public health burden (Churchyard et al., 2014). Biomass smoke has been found to be a significant risk factor for tuberculosis (Kurmi, Sadhra, Ayres, & Sadhra, 2014).

Energy poverty can thus be seen as a bottleneck to improved livelihoods, and recent policies have explicitly targeted energy poverty to unlock access and use of electricity, including the Integrated National Electrification Plan (INEP), the Free Basic Electricity (FBE), the Free Basic Alternative Energy (FBAE), and the Inclining Block Tariff (IBT).

Secondly, the rate and scale of urbanization taking place in SSA in general means that an accurate understanding of the energy-related implications of this process has implications for decision making regarding government electrification programs. Urban populations in SSA are expected to triple by the year 2050, and the proportion of households residing in urban areas is expected to increase from 40% today, to 60% in 2050 (UN-DESA, 2018). In South Africa, the urban population is expected to grow from 39 million in 2020 to 58 million in 2050 (UN-DESA, 2018). Where, for example, should government efforts be concentrated, and how do infrastructural investments impact on migration decisions? In order to successfully tackle energy poverty of the urban poor, it is important that the energy poverty status of rural-urban migrants is well understood.

Thirdly, despite the pervasiveness and dynamism of internal migration in South Africa - a process deeply ingrained in its history and social fabric - studies of migration in Southern Africa in general have only recently begun to benefit from panel datasets and few existing studies have used these to explore the energy landscapes migrants move between (see Dinkelman (2011); Harris et al. (2017)). Finally, an understanding of the implications of migration for the energy transition allows us to broaden the discussion of whether there are gains from migration, and if so, for whom (Garlick, Leibbrandt, & Levinsohn, 2016).

Besides these motivations, the South African case is interesting given the co-existence of both high levels of grid coverage (close to 90%), with high rates of poverty (with a poverty headcount of 55% using the government statistical agency's upper bound line[3] (Sulla & Zikhali, 2018), and high rates of traditional fuel use in rural areas (in 2017, roughly 30% of households in traditional areas[4] cooked mainly with traditional fuels). In addition, South Africa experienced a relatively early structural transformation in the African context and is also relatively urbanized by comparison (roughly two thirds of the population reside in urban areas (UN-DESA, 2018)). However, in large parts of rural[5] South Africa, some of the development challenges, such as a lack of access to government services and infrastructure as well as limited economic opportunities, resemble those of lower-income and other middle-income African economies. The coexistence of these separate contexts presents potential lessons for the future of other SSA countries. While some features about South Africa are specific to its history, others may present a view of what other countries may look like as they also structurally transition and urbanize.

This paper presents the first analysis of the relationship between rural-urban migration and energy poverty in South Africa, and to our knowledge in Africa, using panel data drawn from

[3]Roughly 80 USD per month in 2019 terms.

[4]In South Africa certain areas fall under traditional authority, where customary land tenure rights and a system of traditional courts exist. These 'traditional areas' are largely situated in the areas that constituted the former apartheid homelands before democracy.

[5]Here we refer specifically to areas of rural South Africa that fall under communal tenure arrangements and tribal authorities, where 30% of the population resides and where monetary poverty, unemployment and other forms of deprivation are concentrated. Nearly all of these areas lie in what used to be the former apartheid homelands.

a nationally representative baseline. We make use of the National Income Dynamics Study[6] (NIDS), spanning a period of ten years, and in which both migrants and non-migrants can be tracked in each wave to explore how the energy use-profiles of rural-urban migrants change with migration, compared to rural stayers. We ask whether and how migrants to urban areas are better off from an energy poverty perspective and how this depends on the choice of destination.

We focus on rural-urban migration, given its association with the systemic process of urbanization in the country and its relevance for understanding the implications of this change[7]. Our empirical strategy is based on a difference in differences (DiD) approach, following that of Beegle, De Weerdt, and Dercon (2011) and Cockx, Colen, and De Weerdt (2018) (both in the case of Tanzania)- who also use panel datasets and a difference in differences approach to study the development implications of migration- but applied here to the case of energy poverty and also using propensity score matching. As a general measure of energy poverty we use the Multidimensional Energy Poverty Index (MEPI) proposed by Nussbaumer, Bazilian, and Modi (2012). We also explore changes in some of its components, as well as including an expenditure-based measure used by the South African government. The use of panel data allows us to control for forms of unobserved fixed individual heterogeneity that may be associated with both the decision to migrate and with energy outcomes, such as risk aversion or fixed individual preferences. We adopt a range of approaches to control for the selection problem that is inherent to non-experimental studies of migration (McKenzie, Stillman, & Gibson, 2010). We control for a range of observable variables correlated with migration decisions and in our preferred specification, match migrants to observationally similar non-migrants. As a robustness check, given that the NIDS panel consists of five waves, we are able to compare energy poverty changes experienced by migrants early-on in the panel to contemporaneous changes for a group consisting only of rural residents who would them-

[6]The NIDS data is publicly available here: `http://www.nids.uct.ac.za/`

[7]This is not to suggest that migration in South Africa is characterized as only rural to urban. Garlick et al. (2016) have shown that the majority of migration in fact occur within urban areas.

selves migrate later on in the panel.

We observe firstly that energy outcomes are changing rapidly in South Africa and that indeed even rural energy access and energy poverty is not stagnant but changing rapidly. Using the MEPI headcount ratio which takes into account a broad array of energy access variables, energy poverty on a national scale decreases by close to 20 percentage points over the period of the panel, from close to 30% in 2008 to 10% in 2017. This stands in stark contrast to the situation with monetary poverty which has fallen by less than 10%. We find that rural-urban migration results in additional reductions in multidimensional energy poverty for migrants themselves, with pronounced reductions in the use of traditional cooking fuels – a major cause of lower-respiratory disease. Interestingly, the additional gains from migration are smaller than what might be expected, given the pace of change in energy access that is also taking place in rural areas, especially in the case of grid access and access to electrical appliances. However, while electricity access in rural areas is improving rapidly, individual level energy use behaviour in terms of cooking fuels is slower to change. Finally, there is a significant share of rural-urban migrants who move into informal dwellings. For these migrants, additional energy-access gains from migration are negligible.

2 Background: Household energy access in South Africa

South Africa's mass electrification program in the democratic era has been remarkably successful in expanding access to electricity. The country moved from a 20% to a 80% electrification rate in a period of 27 years (Blimpo & Cosgrove-Davies, 2019), and established 7.4 million new household connections in the period 1994-2018 (DOE, 2019). In addition, a Free Basic Electricity policy[8] was introduced to improve access and use for the poor. The national

[8]The precise amounts and conditions for free electricity vary across municipalities, but they usually require the household to be registered as 'indigent' and in Cape Town, for example on a monthly basis, 60kwh free electricity is provided for households with consumption under 250kwh per month and 25kwh free electricity is provided for households with consumption between 250-450kwh per month. For comparison,

electrification programme had an urban focus in the 1990s until 2002. Then, more emphasis was given on rural electrification which has been far more costly and labour intensive and slowed down the connection rates (Bekker, Gaunt, Eberhard, & Marquard, 2008). When the population is scattered, infrastructure is more expensive.

The South African government's large scale investments in the provision of over three million formal houses, through the Reconstruction and Development (RDP) and Breaking New Ground (BNG) subsidy housing programs, have also made significant contributions to broadening energy access (Franklin, 2020). Franklin (2020) finds that access to subsidy housing results in significant increases in electricity access for informal households in Cape Town and posits that time saving associated with electricity access is one of the avenues through which housing improves women's labour supply.

Table 1 illustrates some of these successes, showing large improvements in energy access rates over the ten year period 2008-2017 covered by the NIDS panel. Table 1 also shows that there is significant variation in energy access by type of settlements. For example, in the period 2008-2017, grid access has improved much more rapidly for individuals living in Tribal authority areas (66%-87%) than for those living in urban free standing shacks (55%-69%) or back-yard shacks (78%-83%). Energy access in informal urban dwellings is also significantly higher in back-yard shacks compared to free-standing shacks.

Harris et al. (2017) find that despite aggregate gains in electricity access, the process of electrification has not been monotonic, with disconnections, new-household formation and dissolution resulting in periodic declines in net connections, even in a context of an improvement in aggregate access. The roll out of both grid and off-grid technologies to comparatively more stable[9] rural areas, through the governments Integrated National Electrification Program, has been relatively successful, despite lower levels of overall access to the grid than urban areas. This leads Harris et al. (2017) to suggest that rural electrification coupled with the role of new household formation as a result of rural-urban migration may have led to

average consumption in the United States is 867 kwh per month.

[9]Stable in terms of the rate of new household formation.

Table 1: Energy access by settlement type

	Tribal authority areas		Formal rural areas		Urban back yard shacks		Urban shacks not in back yard		Urban formal housing		Total	
	2008	**2017**	**2008**	**2017**	**2008**	**2017**	**2008**	**2017**	**2008**	**2017**	**2008**	**2017**
Main cooking fuel:												
Electricity	41.39	69.09	52.10	66.68	63.16	84.50	43.44	70.97	90.30	92.82	68.34	82.95
Gas	1.83	2.65	1.03	3.81	2.20	4.88	3.90	5.03	3.30	4.57	2.68	3.99
Paraffin	14.78	2.19	8.86	7.32	28.84	9.07	48.72	19.32	3.15	0.96	10.63	2.90
Wood	40.10	25.02	35.15	20.30	0.12	0.80	3.64	1.64	0.51	0.57	15.94	8.96
Main lighting fuel:												
Mains electricity	66.75	91.29	57.64	75.61	76.48	86.95	54.65	74.37	96.27	98.45	81.29	93.54
Paraffin	5.42	1.28	4.68	1.74	4.93	1.84	14.00	6.26	0.35	0.26	3.18	1.00
Candles	27.16	5.66	33.75	18.99	18.41	10.17	30.18	17.42	1.97	0.51	14.27	4.18
Solar energy	0.24	1.19	2.91	2.18	0.00	0.41	0.00	1.10	0.00	0.05	0.25	0.56
HH has electricity:	66.48	87.42	59.52	69.81	78.24	83.73	55.98	69.32	95.70	94.91	81.18	89.74
Electrical appliances:												
HH access to a elec/gas stove	48.80	84.71	56.59	76.70	63.94	89.15	49.82	75.48	85.38	96.37	68.83	90.58
HH access to a fridge	43.73	78.15	49.05	68.18	33.78	70.15	39.10	61.10	77.86	92.38	61.27	84.40
HH access to a radio/TV	80.52	87.60	85.55	82.71	80.51	84.34	76.72	78.31	93.81	94.44	87.53	90.57
HH access to a cell/telephone	76.59	92.55	76.60	91.88	75.40	89.18	73.60	87.00	88.42	94.26	82.57	93.04

Source: Own calculations using SALDRU (2008, 2017). *Notes:* The table presents weighted average access rates (presented as percentages) for individuals, by living area. N=27,149 and 39,585 individuals with complete information for these variables, in 2008 and 2017 respectively. Urban areas have been disaggregated by dwelling type. In the case of cooking and lighting fuels, column totals do not add up to exactly 100 due to a number of additional categories (animal dung, coal, etc) with less than 1% adoption.

a situation where some rural-urban migrants move from serviced rural areas to unserviced informal urban areas. Here we build on the work of Harris et al. (2017) by using a panel data approach to follow how energy poverty outcomes change for individuals as they migrate from rural to urban areas in South Africa.

Municipalities are a major actor of electricity provision to households in South Africa. While the majority of energy generation and transmission is carried out by ESKOM, the state-owned energy utility, roughly half the electricity produced by ESKOM – 87% of which is fossil fuel based (StatsSA, 2018) – is sold to local municipalities that are responsible for the final distribution to consumers (Eberhard, 2003). Municipalities resell electricity bought from ESKOM to households. As such, the administrative and technical capacity of municipalities to meet rising demand in rapidly changing informal urban areas, is a key aspect of facilitating energy access.

Approximately a third of municipal distributors in South Africa face financial difficulties, often due to non-payment of electricity bills (Tait, 2015). In some cases this has resulted in cutoffs of electricity in urban areas (see for example Fiil-Flynn (2001), for a focused discussion of the case of Soweto, Johannesburg and Fjeldstad (2004) for a more general overview of the problem of non-payment). In addition, many households in rapidly forming informal urban areas are not formally connected to the grid due to safety concerns. These households often make use of informal connections[10]. Tait (2015) also finds that despite connection, there are numerous issues relating to the affordability and safety of electricity access facing households in informal areas, leading to the persistence of the use of alternative fuels for some uses.

3 Review of the migration-energy nexus

The migration-energy nexus has not received much attention in the academic literature. There is an obvious gap in the literature that tends to focus on either understanding fuel use patterns in rural or urban settings or exploring economic and non economic benefits of access to modern energy services (Bonan et al., 2017; Muller & Yan, 2018). The linkages that emerge between internal migration and energy poverty are thus not yet well understood as the theoretical relationship between internal migration and energy use is ambiguous and empirical evidence is scant.

Does poor energy access influence the decision to migrate, i.e. is energy poverty a push factor? Or is the availability of energy services a pull factor? The literature provides very little evidence of a relationship between energy poverty and migration decisions. If there is an effect at all, it is more likely due to the fact that access to modern energy sources is correlated with other determining characteristics in the decision to migrate, such as poverty, the lack of economic opportunities and the lack of basic services and infrastructures (roads, health facilities, etc.). As such, energy access is rather considered as an indirect cause of migration via economic and environmental drivers which are expected to be reinforced by

[10] "Informal areas that are not eligible for service delivery include those located on land not proclaimed for housing, backyard dwellers, under high voltage lines, in a road or rail reserve, flood-prone areas or flood plain, storm water retention, where there may be health or safety hazards such as on old landfills or on unstable land, or any households on private land"-(Tait, 2015)

energy poverty or lack of energy infrastructure[11].

Others also argue that electrification programs in rural areas may reduce out-migration (Dinkelman, 2011), or even favour in-migration to grid-connected rural areas. Again, evidence here is scant. In their study of circular migration in urban slums in Nairobi, Kenya, Beguy, Bocquier, and Zulu (2010) find that having access to basic utilities like electricity may decrease the turn-over in these informal settlements. In rural South Africa, Dinkelman (2011) finds that individuals may migrate toward areas which benefit from electrification programmes; conversely, they may leave areas which are not electrified. More broadly, Dinkelman (2011) discusses various transmission channels between rural electrification and the decision to migrate, with a focus on the labor market. Firstly, rural electrification could modify home production – in acting like a technology shock – and could lead to an increase in labour supply for those household members who are most engaged into home production. Secondly, rural electrification may stimulate the job market in these areas and generate opportunities outside of the home. Thirdly, rural electrification may increase opportunities for home production of goods and services for the market such as food and cell phone charging stations. It can thus also be argued that rural electrification – via enhanced access to opportunities – can facilitate out-migration. Posel, Fairburn, and Lund (2006) for example, find that cash transfers to pensioners in rural South Africa have this type of effect on the labour supply of female working age adults.

For those individuals who do migrate, one should make the distinction between access to better energy infrastructure and individual energy poverty, to explicitly account for the fact that an individual may remain energy poor even though he/she has access to the grid network. Typically, rural-urban migrants have access to better energy infrastructure, such as the electricity grid – in South Africa, access in rural areas sits at roughly 67% and at 92% in urban areas (World Bank, 2016). In addition, assuming that these rural-urban migrants

[11] Another strand of the migration literature considers migration as an adaptation strategy to climate change (Cattaneo et al., 2019). This goes beyond the scope of this paper and is not developed further in the current paper which considers electrification as an infrastructure rather than an environmental amenity.

have higher incomes at destination, they can reduce their energy poverty, which can in turn improve their capacity to engage in the labour market. However, those migrants who live in informal settlements may still have poor access to modern energy. Tait (2015), for example, finds that in Manenberg settlement -a mixture of formal and informal dwellings- in Cape Town, of a sample of 150 households, only 50% had direct access to the electricity grid, while others had access through informal connection or no access at all.

The literature on migration and household fuel transition also explores the status of those who benefit from migration. Manning and Taylor (2014) find that Mexican households that send a migrant to the United States and receive remittances are less likely to rely on traditional fuels. This raises a key challenge facing any study on the effects of migration, namely: effects on whom? Migration is a process that often takes place on an individual level. This is especially true in South Africa and many other Southern African countries that have a history of migrant labour (Wilson, 1996, 1976). These individual migrants transition from one household and into another. Garlick et al. (2016) highlight that in these cases, instead of one effect, there are in-fact three effects: the effect on the migrant; the effect on the sending household and that on the receiving household. In this paper, we will focus on the effect on the migrant.

4 Presentation of the data

4.1 The National Income Dynamics Study (NIDS)

The NIDS data spans a period of ten years (2008-2017) and is comprised of five survey waves. It presents a hitherto unprecedented opportunity to study migration in South Africa where the post-apartheid period saw a decline in the coverage in internal migration-related questions in nationally representative surveys (Posel, 2004). In addition, the data contains valuable information related to cooking and lighting fuel use, electricity access and spending on electricity and other fuels, as well as stove type ownership. The 2008 baseline sample of 28,000 individuals in 7,300 households was designed to be nationally representative and selected using a two-stage sampling design with 400 primary sampling units (PSUs) and a target of 24 households per PSU (Brophy et al., 2018). Roughly every two years following this, the same individuals were re-interviewed as Continuing Sample Members (CSMs). Other members who became part of the original households were also interviewed, but not tracked in the subsequent waves and make up Temporary Sample Members (TSMs). Children born to CSM mothers became CSM members themselves. Due to attrition of White, Indian/Asian and high-income respondents, a top up sample was included in Wave 5 (2017) in order to maintain the representativeness of the sample (Brophy et al., 2018). Overall sample attrition is 14-22%, mostly driven by non-responses by wealthier and Asian/Indian and White respondents. Attrition rates in rural areas, where incomes are also lower, and those among black and coloured respondents are much lower.

4.2 Measuring Energy Poverty

Various approaches to measuring energy poverty exist and to date no consensus has emerged from the academic and policy spheres.[12] Supply side approaches rely on physical availability of modern energy sources, physical energy requirements and reliability of energy supply. While the first one doesn't account for reliability and quality of energy supply, the second one is built on a more complex engineering approach. More importantly, these approaches fail to recognize that some households may be living 'under the grid', i.e. where electrification rates are low despite the availability of grid infrastructure (Lee et al., 2016), or may stack energy sources (Choumert-Nkolo, Motel-Combes, & Le Roux, 2019). Demand side approaches relate to the use of various energy sources and deprivations faced by households.

[12] There are extensive discussions on the choice of the indicator, with debates on the type of metric (i.e. a binary metric, a dashboard of indicators, or a composite index), on the approach (i.e. supply-side or demand-side) and the nature of information used to build the indicator. Such discussions are beyond the scope of the paper. See Bhatia and Angelou (2015); Day, Walker, and Simcock (2016); Pachauri (2011); Pelz, Pachauri, and Groh (2018) for comprehensive reviews.

The literature offers numerous measures, such as (i) the lack of the minimum[13] energy needs required for cooking and electricity (Modi et al., 2005), (ii) the threshold point at which energy consumption increases with rises in household income (Barnes, Khandker, & Samad, 2011), (iii) the Total Energy Access (Practical Action, 2013) which combines lighting, cooking, space heating/cooling and information and communications services into one matrix allowing to assess whether households meet minimum standard of access to energy services, (iv) the multi-tier framework which examines access to electricity, to energy for cooking and space-heating (Bhatia & Angelou, 2015), and (v) the Multidimensional Energy Poverty Index (MEPI) that focuses on deprivation of access to modern energy services (Nussbaumer et al., 2012).

In the specific case of South Africa, the South African Department of Energy employs several approaches, namely an expenditure-based approach, a thermal efficiency approach, a subjective approach and a low-income and thermal inefficiency (DOE, 2013)[14]. Following these approaches, 43% of South African households were energy poor with the expenditure-based approach, 49% with the thermal efficiency one, 26% according to the subjective one, and 26% with the low income and low energy efficiency one.

As a general measure of energy poverty we adopt the MEPI, based on the Oxford Poverty and Human Development Initiative (OPHI) Multidimensional Poverty Index (MPI), pro-

[13] "These minimum needs correspond to about 50 kilograms of oil equivalent (kgoe) of annual commercial energy per capita; this estimate is based on the need for approximately 40 kgoe per capita for cooking and 10 kgoe used as fuel for electricity" - (Modi, McDade, Lallement, Saghir, et al., 2005).

[14] The expenditure-based approach defines a household as energy poor if they spend more than 10% of their net income on energy. The thermal efficiency approach relies on the thermal comfort of the dwelling, According to the subjective approach "a household is considered energy poor if it is characterised by one or more of the following attributes: (i) the amount of energy the household uses is reported as being less than adequate for its needs; (ii) the amount of energy the household uses for lighting is reported as being less than adequate for its needs; (iii) the amount of energy the household uses for cooking is reported as being less than adequate for its needs; (iv) the amount of energy the household uses for heating rooms and keeping warm is reported as being less than adequate for its needs.". Finally "a household is considered energy poor as per the low-income and thermal inefficiency approach "if it has less than 60% of South Africa's median per capita monthly income, and meets one or more of the following conditions: (i) the household reports that it is dissatisfied or very dissatisfied with its accommodation; (ii) the state of repair of the household's accommodation is described as "poor"; (iii) one or more of the following problems are reported with the accommodation: lack of adequate heating, a leaky roof, damp walls, floor or foundations, or damaged or broken windows or doors; (iv) the health of a household member has deteriorated due to the housing conditions."-(DOE, 2013)

posed by Nussbaumer et al. (2012)[15] for measuring energy poverty. In short, the MEPI consists of a weighted sum of six different binary energy-deprivation variables outlined in Table 2. Each person i is associated with a level of access y_{ij} to a given binary energy-access variable $j = 1, 2, ...6$, where $y_{i,j}$ takes on a value of 1 if the individual lives in a household considered to be deprived of access, and 0 otherwise, based on a cutoff z specific to each energy access variable j (e.g for cooking fuels, z would be whether the household cooks with modern fuels). Each variable j is also associated with a weight w_j, with $\sum_{j=1}^{j=6} w_j = 1$. Weighted deprivations are counted by a vector c, where $c_i = \sum y_{i,j} * w_{i,j}$ is the weighted sum of deprivations for person i. This counting vector is the main outcome variable in the subsequent analysis. Nussbaumer et al. (2012) provide a description of further derivations of the MEPI Headcount and Intensity indices, which are not central to this analysis.

This measure captures various components of energy poverty, including a lack of grid access, fuel type, indoor air pollution and the ability to make use of electrical appliances. It allows us to explore energy poverty in general, but also in which dimensions of the MEPI energy poverty is experienced. In addition, the data used for these dimensions are generally of good quality (unlike indicators based on expenditures), and widely available in household surveys in South Africa. Another advantage is that it captures both the availability of energy (here electricity) and also how energy is used. While the MEPI excludes explicit affordability, affordability is indirectly measured, through capturing use. Similarly, this measure does not capture availability and reliability as observed by Pelz et al. (2018) and Tait (2015), but we argue that grid reliability in South Africa is generally high in the SSA context[16].

In order to ensure comparability, we adopt the same weights as Nussbaumer et al. (2012) and an initial poverty cut-off of k=0.3 (i.e. a person is considered multidimensionally energy

[15] In their multi-country comparison of energy poverty in Africa, Nussbaumer et al. (2012) make use of DHS data which is available for the 29 countries in their analysis. However, as the DHS survey had not been recently conducted in South Africa, it was excluded from that study. While the wording is not identical, all the variables used by Nussbaumer et al. (2012) are available in the NIDS data.

[16] It would be inaccurate to say that South Africa does not have serious reliability challenges. Load-shedding (scheduled power cuts) does occur and is of serious concern for businesses, and has become exacerbated in recent years. However, in the broader African context, electricity interruptions in South Africa are relatively infrequent.

Table 2: MEPI variables and weights

Variable	Definition	Indicator	Weight
Cooking deprived	=1 if the HH does not cook with electricity, solar or gas	Modern cooking fuel	0.2
Lighting deprived	=1 if the HH does not have access to the electricity grid	Electricity access	0.2
Stove quality deprived	=1 if the HH does not own an electric or gas stove	Indoor pollution	0.2
Deprived: Fridge	=1 if the HH does not own a fridge	Household appliance ownership	0.13
Deprived: Communication	=1 if the HH does not own a telephone or cell phone	Telecommunication means	0.13
Deprived: Information	=1 if the HH does not own a radio or television	Entertainment/education appliance	0.13

Source: adapted from Nussbaumer et al. (2012). *Notes:* The analysis in this paper is undertaken at the individual level because the majority of internal migrations in South Africa take place at the individual and not the household level. However, many of the energy access variables are measured at a household level (Garlick et al., 2016). We assign to individuals the energy access variable according to household responses.

poor if $c_i > k$) for the MEPI headcount ratio shown in descriptive statistics. The variables that are included in the MEPI and their respective weights are shown in Table 2. Figure 11 and in the appendix provides an overview of the MEPI headcount and intensity changes over the period of the panel, on a national level. In regressions the uncensored MEPI counting vector is rendered strictly positive (by adding 1) and then logged.

Figure 1, provides an overview of the evolution of the South African MEPI headcount poverty ratio over time, as well as the six variables that constitute it. In addition, the monetary-poverty headcount ratio using the Statistics South Africa[17] upper bound poverty line is displayed for comparison. ~~It shows that energy poverty, as measured by the MEPI has declined by close to 20 percentage points in the period~~ from 2008 to 2017, from 30% to 10%. In addition, the reduction in energy poverty as measured by the index is not limited to just one variable but declines in deprivation are consistent across all variables in the index. Also, of note is that energy poverty has declined much faster than monetary poverty, which has declined by less than 10 percentage points over the same period. The second panel of Figure 1 illustrates rural and urban differences in energy and monetary poverty over the period of the panel. It makes clear that the major reason for the reduction in the National MEPI headcount ratio in the first panel, is the rapid decline in energy poverty in rural areas, where the MEPI headcount ratio fell by 30% over this ten year period.

Figure 2 presents mean electricity expenditure as a ratio of total expenditure by household

[17] The government statistical department.

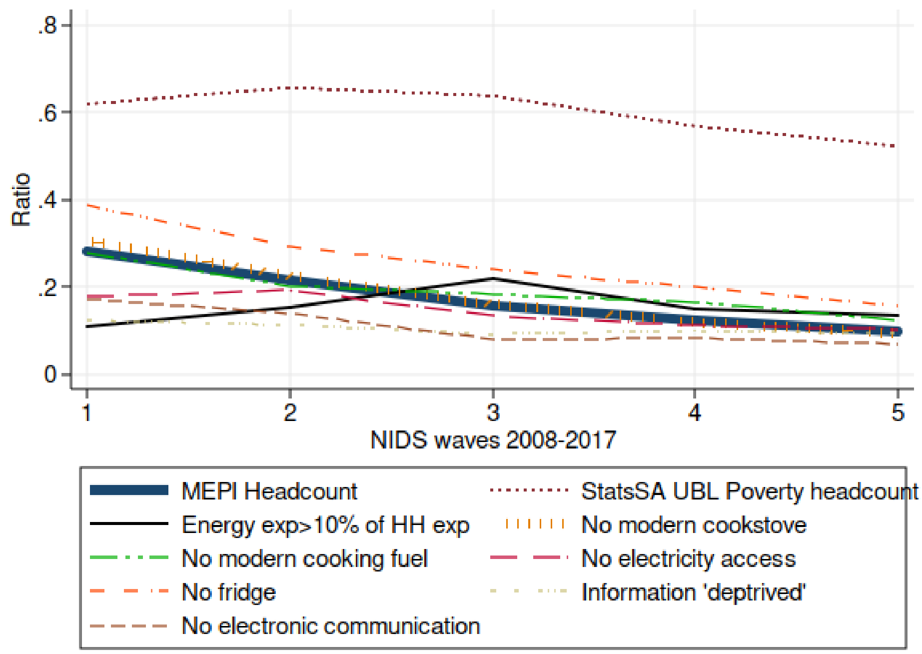
per capita expenditure ventile for the entire NIDS sample from wave 1 to wave 5. The large real increase in household spending on electricity as a ratio of total household expenditure observed between waves 2 to 3 is likely due to the combination of ESKOM tariff increases and the introduction of increasing block tariffs around this time[18]. A notable aspect of this graph is that there is a larger difference in the ratio between rich and poor households from wave 3 onwards than there was in the first two NIDS waves[19]. Figure 2b plots the same ratio, but for non-electricity energy expenditure over the per capita expenditure distribution.

[18] An overview of these tariff changes can be found on the ESKOM tariff history page: https://www.eskom.co.za/CustomerCare/TariffsAndCharges/Pages/Tariff_History.aspx

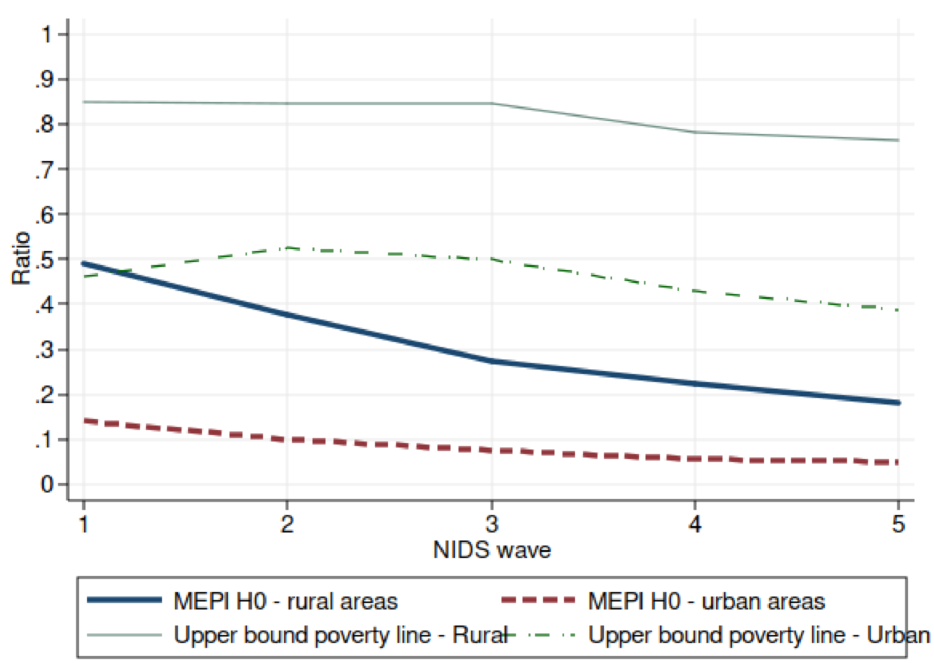
[19] This is not necessarily due to the tariff structure.

Figure 1: MEPI headcount compared to monetary poverty: 2008-2017

(a) MEPI headcount and its constituents compared to monetary poverty



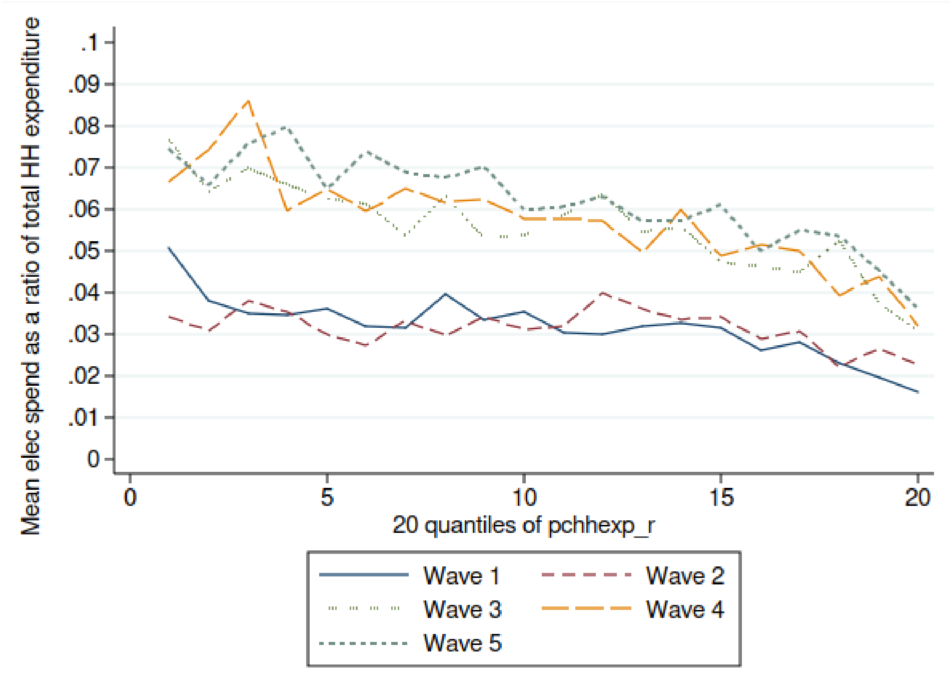
(b) Rural and urban differences in MEPI headcount vs. monetary poverty



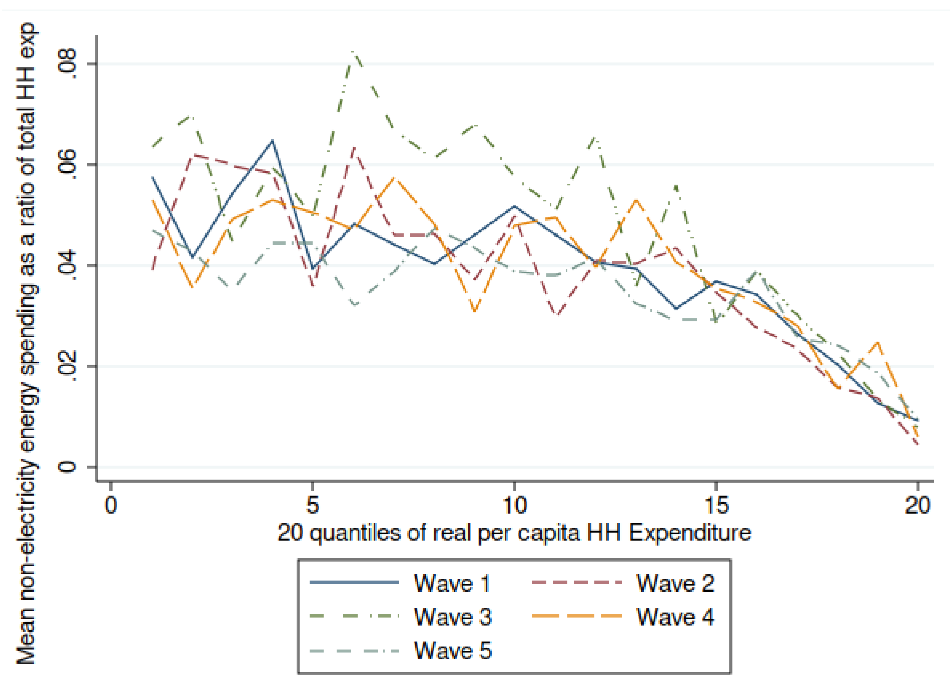
Source: Own calculations based on NIDS waves 1-5 SALDRU (2008, 2010, 2012, 2014, 2017). *Notes:* The sample here contains all NIDS individuals. StatsSA poverty headcount based on the upper-bound line of R1136 (8̃0USD) per person per month in March 2017 terms. MEPI headcount for k=33.33. The 10% energy expenditure threshold is that used by the Department of Energy.

Figure 2: Electricity and non-electricity energy spending over the expenditure distribution

(a) Electricity spending as a ratio of household expenditure, over the expenditure distribution



(b) Non-electricity energy spending as a ratio of household expenditure, over the expenditure distribution



Source: Own calculations using SALDRU (2008, 2010, 2012, 2017, 2017).

4.3 Migration in the NIDS panel

In this analysis, we focus on the energy-access implications of rural-urban migration. We are mainly interested in how energy-access and use changes as individuals migrate between different areas, in light of the longer term process of urbanization taking place in South Africa and the region as a whole. Following the reasoning of Garlick et al. (2016), we decide to focus this analysis on black and coloured[20] respondents. There are numerous reasons for this. The type of rural-urban migration in South Africa that we are interested in here concerns residents that a) originate in rural areas that fall under traditional authorities[21] and b) are farm workers on commercial farms. White and Indian/Asian respondents nearly as a rule do not generally fall into either of these categories and do not form part of the major dynamics of internal migration in South Africa (Garlick et al., 2016). In addition, attrition of white (50% between waves 1-3) and Indian/Asian respondents is both very high. Roughly 80% of the South African population are classified as "Black African" with an additional 9% being classified as Coloured. As such, these exclusions do not constitute a distortion of the major dynamics of migration in South Africa.

We find that 10% of the Wave 1 (2008) rural residents are observed to move 'mono-directionally' to an urban area at some stage between waves 1 to 5 and remain in an urban area in all subsequent waves (i.e. not be observed to be resident in a rural area in any period after the initial migration, over the course of the panel). However, many rural residents observed in 2008 move to an urban area and then return to be resident in a rural area at some stage in the panel. In this light, 19% of Wave 1 (2008) rural residents would be observed to be living in an urban area at least once between Waves 2 and Wave 5. The proportion of urban-to-

[20]In South Africa, the racial classifications developed and used under apartheid are still used by the government statistical agency, partly because they continue to be accurate markers for disadvantage. Coloured South Africans are culturally distinct group of people of 'mixed-race' origin.

[21]Rural South Africa is generally seen as comprised of two distinct institutional environments: Traditional areas that are usually under tribal authority and communal land tenure; and commercial farms. This dualism is fundamentally a product of colonial and apartheid policies, with the majority of traditional areas today falling into the boundaries of what used to be the apartheid homelands, and commercial farms usually controlled by white commercial agriculture, but on which farm workers who are nearly exclusively black and coloured reside.

rural migrations of this type is much smaller (6%). In addition, 52% of Wave 1 individuals resident in rural households would be affected by out-migration of household members to an urban area over the next ten years, by 'sending' at least one person to an urban area. 17% of individuals resident in urban households in 2008 would be affected by out-migration to a rural area.

Table 3, shows the evolution of the wave 1 baseline sample of rural residents with respect to their area of residence. 13%[22] of respondents who had been resident in rural areas in 2008 (Wave 1) were observed to be living in an urban area in 2017. Table 4 shows the percentage of rural residents in wave t who would be observed to be resident in an urban area in wave $t + 1$. For example, the W4 column of Table 4 shows that 4.2% of wave 4 rural residents would be observed to be living in an urban area in wave 5. On a wave-to-wave basis[23], on average 4% of rural NIDS residents are located in an urban area in the next wave over the course of the NIDS panel.

Figure 3 presents the data in a different way. It restricts the sample to wave 1 (2008) rural residents observed in all subsequent waves of the NIDS survey and follows the living locations of these respondents over the ten year period to 2017. This is a strong condition and this restricted sample is likely prone to some selection induced bias. Nonetheless the figure provides an idea of the dynamics of migration between rural and urban areas. It also provides an indication of the relative magnitude of circulating or oscillating migration between rural and urban areas, a process that has a long history and is common South Africa (Posel, 2004; Posel & Marx, 2013).

All migration information in the NIDS data should be caveated by the fact that we are not able to observe migrations in the periods between waves. For example, a respondent might be observed in the same rural area in waves one and wave two, and thus be classified

[22]The statistics reported in this section relate to Black and Coloured South Africans, for reasons explained in the text.

[23]Without the condition that migrants should be observed in all five waves

Table 3: Locations of Wave 1 rural respondents in subsequent waves

		Rural	Urban	Not interviewed
Wave 1	individuals	13 969		
	households	3 350		
Wave 2	individuals	11 315	335	2 255
	households	3 049	219	
Wave 3	individuals	10 753	972	2 232
	households	3 341	680	
Wave 4	individuals	9 823	1 674	2 468
	households	3 725	1 264	
Wave 5	individuals	8 958	1 853	3 156
	households	3 738	1 435	

*Source:*Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017).*Notes:* Unweighted observation counts from the NIDS data. The table presents where respondents who were successfully interviewed in Wave 1 in a rural area, are observed in subsequent waves. The sample is limited to black and coloured South Africans, following the motivations of Garlick et al. (2016) and explained in the text. Where totals (rural+urban+attrition) in subsequent waves do not exactly add up to Wave 1 totals, this is due to a small number of observations with missing location data.

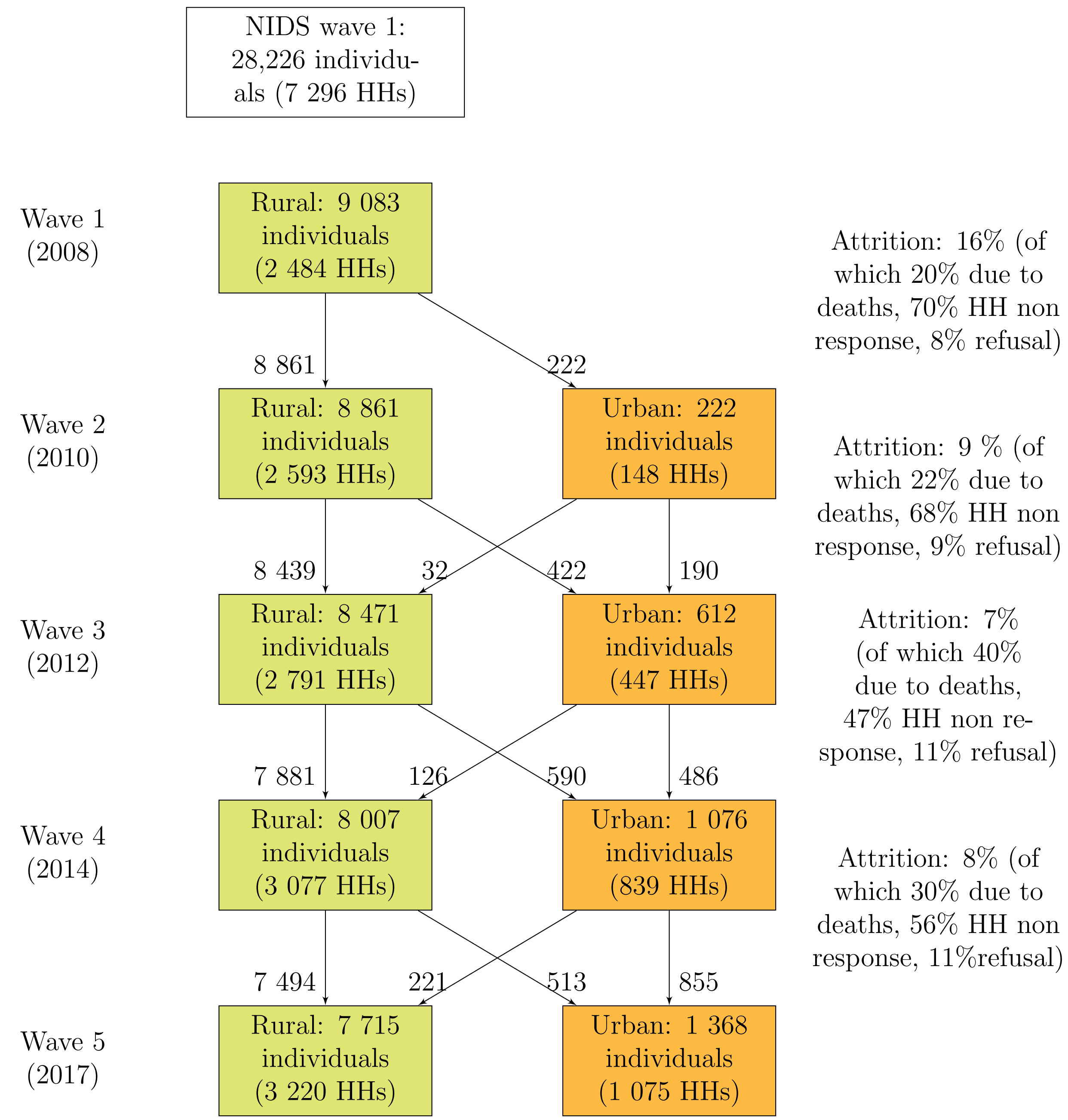
Table 4: Percentage of rural respondents located in urban areas in the next wave

	W1 (2008)	W2 (2010)	W3 (2012)	W4 (2014)	Average:
Percentage urban in next wave	2.3%	4.1%	5.6%	4.2%	4.05%

Source: Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017). *Notes:* This table displays the percentage of respondents in wave t who would be located in an urban area in wave $t+1$., on a wave by wave basis. The sample is limited to black and coloured South Africans.

as a 'non migrant' but may have moved to an urban area in the two-year period between the waves and returned by wave 2.

Figure 3: Location evolution of Wave 1 rural respondents who are observed in all subsequent waves



Source: Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017). *Notes:* This figure restricts the sample to respondents living in rural areas in Wave 1, and who are then successfully re-interviewed with complete location information in all subsequent waves. The sample excludes white and indian/asian respondents for reasons elaborated in the text, following Garlick et al. (2016). Attrition is reported on a wave by wave basis.

4.4 Migration to formal urban versus migration to informal urban areas

We also extend the analysis by differentiating between migration to formal and informal urban dwellings in order understand the extent of heterogeneity of energy outcomes associated with rural-urban migrations to these two different areas. We distinguish migrants by the type of urban dwelling they move to, and thus focus on migrants who move into shacks in or outside of backyards in the wave directly after migration[24]. Table 5 presents the type of housing rural-urban migrants are observed to be living in, in the wave directly after migration. Strikingly, it suggests that one in five rural-to-urban migrants move into either free standing shacks or shacks in back-yards.

Table 5: Dwelling types of new urban residents in the wave directly after migration from a rural area

	Wave 2 (2008)		Wave 3 (2010)		Wave 4 (2012)		Wave 5 (2014)	
	Count	%	Count	%	Count	%	Count	%
Formal brick dwelling	239	71.77	477	74.76	685	71.28	926	70.58
Shack not in back yard	44	13.21	78	12.23	125	13.01	209	15.93
Shack in back yard	28	8.41	58	9.09	107	11.13	146	11.13
Traditional dwelling	22	6.61	25	3.92	44	4.58	31	2.36
N=	333	100	638	100	961	100	1312	100

Source: Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017) *Notes:* The table shows unweighted counts of the dwelling types of new urban arrivals from rural areas in each wave of the NIDS data. For example, the Wave 3 counts show the breakdown of dwelling types or urban residents who were observed to be living in a rural area in NIDS Wave 2.

4.5 Covariates

Table 6 presents an overview of the outcome and control variables included in the subsequent regression analysis. Summary statistics are provided in the appendix.

[24]The NIDS data does contain a $w`i'geo$2001 variable derived from the 2001 census, that classifies areas as “Formal urban areas” or “Informal urban areas”. However, this classification is limited in that areas that were classified as informal in 2001 are likely to have changed significantly by 2010 when the first migrants are recontacted in the NIDS survey.

[25]Many households in urban informal settlements have informal connections via a secondary market for electricity that has emerged in the absence of formal municipality grid connections. See (Tait, 2015) for an overview in Cape Town.

Table 6: Outcome and control variables

	Variable	Description
Energy variables	Grid connection	= 1 if the HH has any form of electricity connection[25]
	Modern lighting	= 1 if the HH's main fuel for lighting is either electricity, solar or gas
	Modern cooking	=1 if the HH's main cooking fuel is either electricity, solar or gas
	Owns elec/gas stove	=1 if the HH owns at least one electric and/or gas stove
	Buy electricity	= 1 if the HH bought electricity in the past 30 days
	Spending on electricity	Amount of money spent by the HH on electricity in the past 30 days (Rands)
	Buy other fuels	= 1 if the HH spent money on other fuels (not electricity) in the past 30 days
	Spending on other	Amount of money spent on other fuels in the past 30/days (Rands)
	Fridge	= 1 if the HH owns at least one fridge
	Cellphone and/or telephone	= 1 if the HH owns at least one cell phone and/or telephone
	TV and/or radio	=1 if the HH owns at least one radio and/or television
	Elec stove	=1 if the HH owns at least one electric stove
	Gas stove	=1 if the HH owns at least one gas stove
	Paraffin stove	=1 if the HH owns at least one paraffin stove
Control Variables	Log per capita household expenditure	Log (total monthly household expenditure/HH size)
	Female	= 1 if the respondent is female
	HH head female	= 1 if the HH head is female
	HH size	Number of people who usually reside at the HH for at least four nights a week
	Age	Age of the respondent (years)
	Age squared	Ageˆ2
	Years of education	Years of completed education
	HH head education	Years of completed education of the HH head
	Employed	= 1 if the respondent is employed (formally or informally)
	HH head employed	= 1 if the HH head is employed (formally or informally)

5 Empirical strategy

Given the length of the NIDS panel, there are multiple different ways to approach an analysis of the returns to migration. On the one hand, it is possible to use the 2008 sample of rural residents as a pre-migration baseline and then estimate returns in subsequent waves. On the other hand, it is possible to estimate wave-to-wave returns at later stages in the panel, and over varying lengths of time. It is also possible to restrict the analysis to mono-directional[26] migrations in line with Beegle et al. (2011).

In order not to limit the results to an arbitrary choice of specification, we include a range of different estimates in the ensuing analysis. Table 7 provides an overview of the different samples identified. The first four rows use wave 1 (2008) rural respondents as a baseline and then return to these respondents in subsequent waves, marking those residing in an urban

[26]Migrants who move from a rural area to an urban area and do not move back to a rural area.

area as a migrant and those who had remained in the same rural location as a non migrant[27]. The next three rows of Table 7 shift the baseline year and measure wave-to-wave migrations.

Table 7: Overview of samples in the analysis

	Location of migrants						
Estimation period	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5	Migrants	Nonmigrants
w1-w2	rural	urban				335	10,913
w1-w3	rural		urban			972	9,261
w1-w4	rural			urban		1,674	7,361
w1-w5	rural				urban	1,853	6,015
w2-w3		rural	urban			640	11,544
w3-w4			rural	urban		968	11,660
w4-w5				rural	urban	807	14,501
w1-w2-w3	rural	urban	urban			234	8,843
w2-w3-w4		rural	urban	urban		451	8,555
w3-w4-w5			rural	urban	urban	638	8,940
w1-w2-w3-w4	rural	urban	urban	urban		184	6,857
w2-w3-w4-w5		rural	urban	urban	urban	340	6,766
w1-w2-w3-w4-w5	rural	urban	urban	urban	urban	143	5,524

Source: Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017). *Notes:* Each row represents a different sample in the ensuing analysis. In each case, only the locations of migrants are shown. Non migrants are by definition located in rural areas in all waves associated with each sample. The first four rows place the least restrictions on the sample, i.e. they only require successful interviews in two adjacent waves of the panel. The sample sizes differ from wave to wave as a result of new continuing sample members in the NIDS data.

The final six rows of Table 7 restrict the analysis to mono-directional migration and track outcomes over a longer period of time. In this regard, it is possible to observe three migration "settings" spanning three waves (where migrants are located in rural area a in wave t and in an urban area $b \neq a$ in both waves $t+1$ and $t+2$). Similarly, two migration settings spanning four waves and one event spanning five waves (i.e. the person migrates in the first wave and is tracked in the new location in all subsequent waves). In each of these cases, the comparison group would be respondents remaining in the same rural areas for the period in question.

[27]Note that here, in order to be defined as a migrant, the only condition is that the respondent is located in an urban area in the end-line wave. Where the person is located in the waves between the baseline and end-line is not taken into account. The comparison group of non migrants are observed in the same rural location in all waves up to the end-line wave.

Returns to migration may vary based on the time after migration. Adopting an approach where these returns can be estimated over different time periods allows us to understand whether returns change with time. As such, the regression results present outcomes for all the different estimation periods presented in Table 7.

The figures in Table 7 show counts of rural to urban migration by specification. We extend the analysis by also differentiating the results by whether a migrant moves into a formal or informal[28] urban structure. We also include results for rural to rural migrations. In all of these cases, the basic logic of the specification is the same as that in Table 7, it is only the definition of a migrant that changes.

5.1 Difference in Differences

In light of the rapid increases in energy access shown in rural areas in Table 1, we ask whether migrants experience additional gains from rural to urban migration and how this changes by type of destination. We adopt a differences in differences approach, following Beegle et al. (2011) and Cockx et al. (2018) who also use this approach to understand the effects of migration for internal migrants, but we match migrants to observationally similar non-migrants on a set of covariates. This implies comparing the pre-and-post differences in energy poverty of migrants and non-migrants in the pre-migration wave to those in the post-migration wave, for the sample of successfully contacted respondents in each wave. This is specified as follows:

$$\triangle EP_{i,(t,t+x)} = \alpha + \delta M_i + \beta X_{it} + e_{it} \tag{1}$$

Where $\triangle EP$ is the change in energy poverty measure of interest from wave t to wave $t + x$ for individual i, M_i is a binary variable indicating whether individual i is a migrant, $X_{i,w}$ is a vector of observable covariates that may affect both migration and energy poverty measures, and e_{it} is a random error term. The coefficient of interest is δ . A DiD estimator estimates the

[28] We classify free standing shacks, backyard shacks and traditional housing as informal and brick dwellings as formal housing, using the *w'i' h dwltyp* variable.

coefficient δ as the pre-and-post differences of migrants, minus the pre-and-post differences of non-migrants:

$$\hat{\delta}_{DD} = (\overline{EP}_1^{M=1} - \overline{EP}_0^{M=1}) - (\overline{EP}_1^{M=0} - \overline{EP}_0^{M=0}) \tag{2}$$

Where $\overline{EP}_{1,0}$ is the sample mean of the outcome variable conditional on covariates in the particular wave (0 = pre-migration, 1 = post-migration). While we do not have an exogenous shock that results in migration of a sub sample of respondents, the benefit of DiD estimator is that it is able to control for individual fixed heterogeneity that is constant over time and may be correlated with selection into migration and energy outcomes, such as family upbringing and cultural factors and risk aversion. Under the condition that the parallel trends[29] condition is met (i.e. that migrant status is independent of welfare outcomes other than through the effect of migration), $\hat{\delta}_{DD}$ yields the average treatment effect on the treated. As highlighted by McKenzie et al. (2010), failing to control for the selection problem inherent in any study of the effects of migration results in biased estimates. There are two fundamental selection effects. The first of these is in the decision to migrate and the second is in the choice of destination.

In order to control for these potential sources of endogeneity we follow various steps. Firstly, we include individual and household level baseline controls that are likely to affect both migration and energy outcomes, such as household size, per capita household expenditures, access to the labour market, province of origin, the number of children, whether the respondent is married and household head characteristics. These variables are standard in the literature, due to their strong theoretical links to energy poverty outcomes. In particular, we also control for pre-migration household per capita expenditure. In our preferred specification, we estimate DiD coefficient on migration using propensity score matching in order to match observably similar respondents based on the aforementioned covariates.

As a robustness check, we also compare the outcomes of migrants early on in the panel to a comparison group composed of migrants who would migrate later on in the panel but

[29]We present plots of unconditional pre-and post migration trends in the appendix.

had not yet migrated at the end-line period in the difference in differences estimation. This allows us to compare the effects of migration between respondents that all took the decision to migrate, but at different times in the panel.

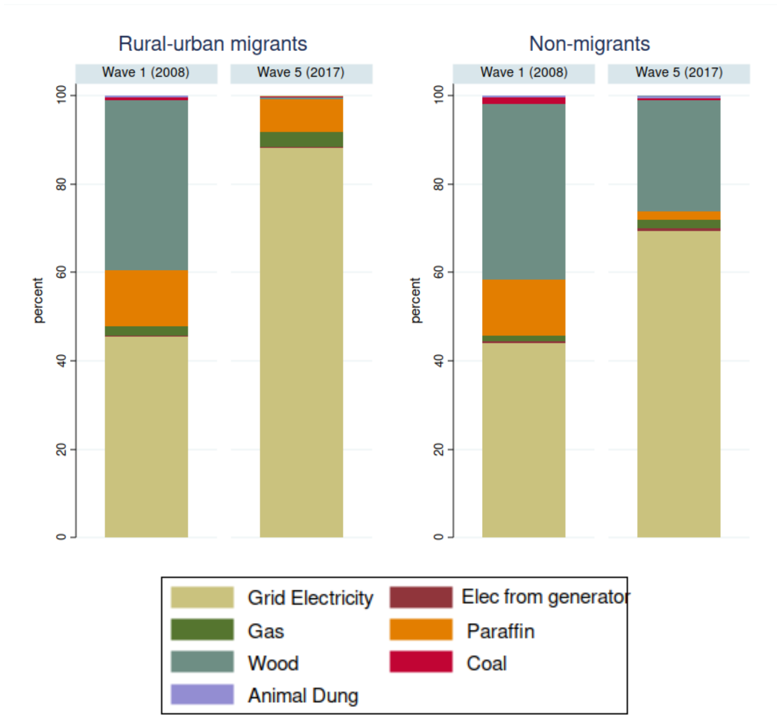
6 Results

Table 8 presents mean energy access and control variables for migrants and non-migrants in wave 1 (2008) and wave 5 (2017), respectively. It also presents t-test statistics for the equivalence of the means between migrants and non-migrants in each wave (columns 3 and 6). All observations in columns 1 and 2 of Table 8 are rural residents, but respondents in column 2 would have migrated to an urban area at some stage by wave 5 (2017) of the survey. Respondents in column 4 are rural stayers who remained in the same rural area and those in column 5 are the rural-urban migrants.

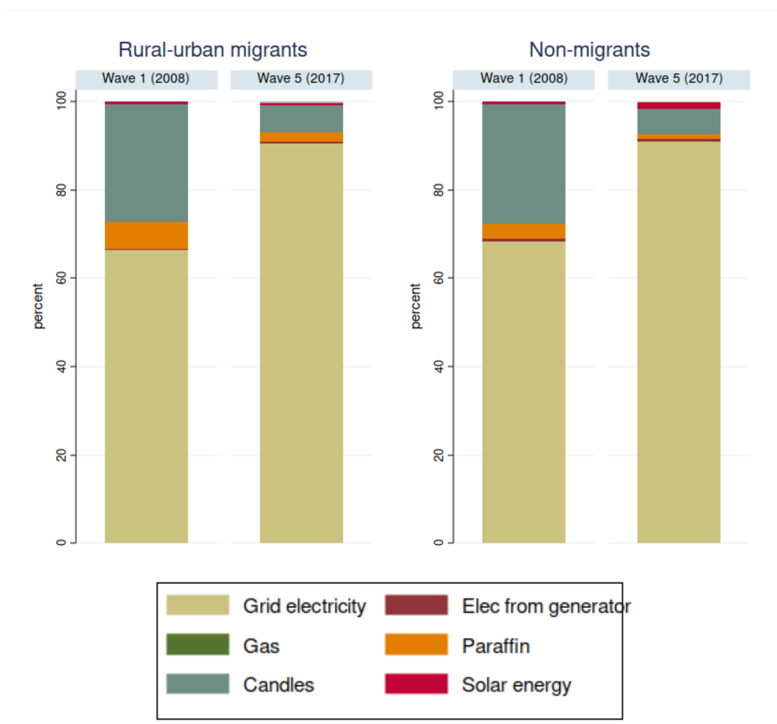
The table provides preliminary evidence suggestive of a significant decrease in energy poverty associated with rural-to urban migrations, but it also suggests that migrants and non-migrants are not homogeneous, given significant differences in covariates with migration in wave 1, illustrating the importance of controlling for selection into migration. Figures 4 (a) and (b) and Figure 5 provide some descriptive evidence of the qualitative changes in energy use associated with migrating to an urban area. They suggest that the major change in energy use associated with moving to an urban area is driven by migrants switching from mainly cooking with traditional biomass fuels to electricity/gas or paraffin when moving to an urban area.Figure 5 shows that rural stayers also experience significant improvements in energy access over the period of the NIDS panel. This is driven by an increase in access to electrical appliances.

Figure 4: Cooking and lighting fuel use by migration status

(a) Main Cooking Fuel, by Migration status

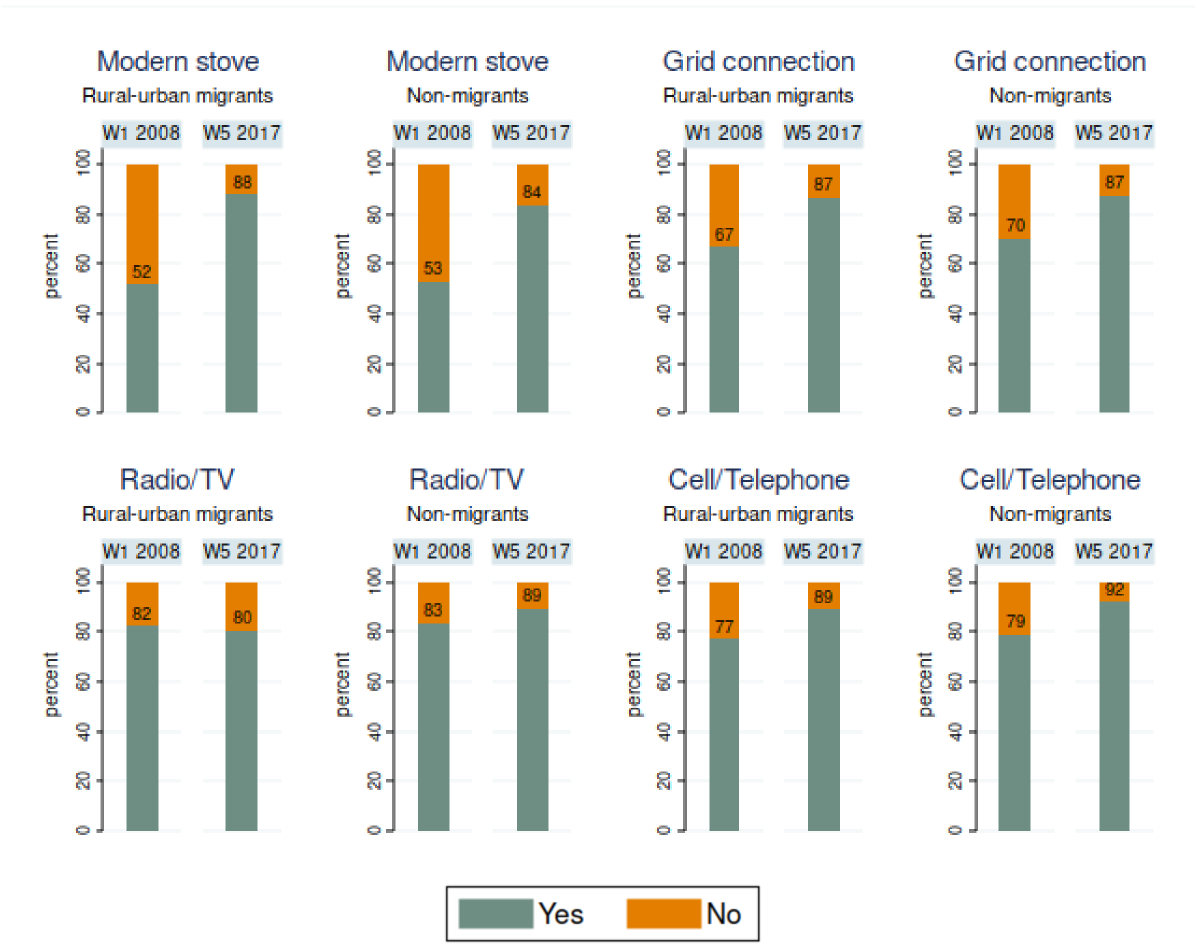


(b) Main Lighting Fuel, by Migration status



Source: Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017)

Figure 5: Additional measures of energy access, by Migration status



Source: Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017)

Table 8: Wave 1 and Wave 5 differences in outcome and control variables between migrants and non-migrants

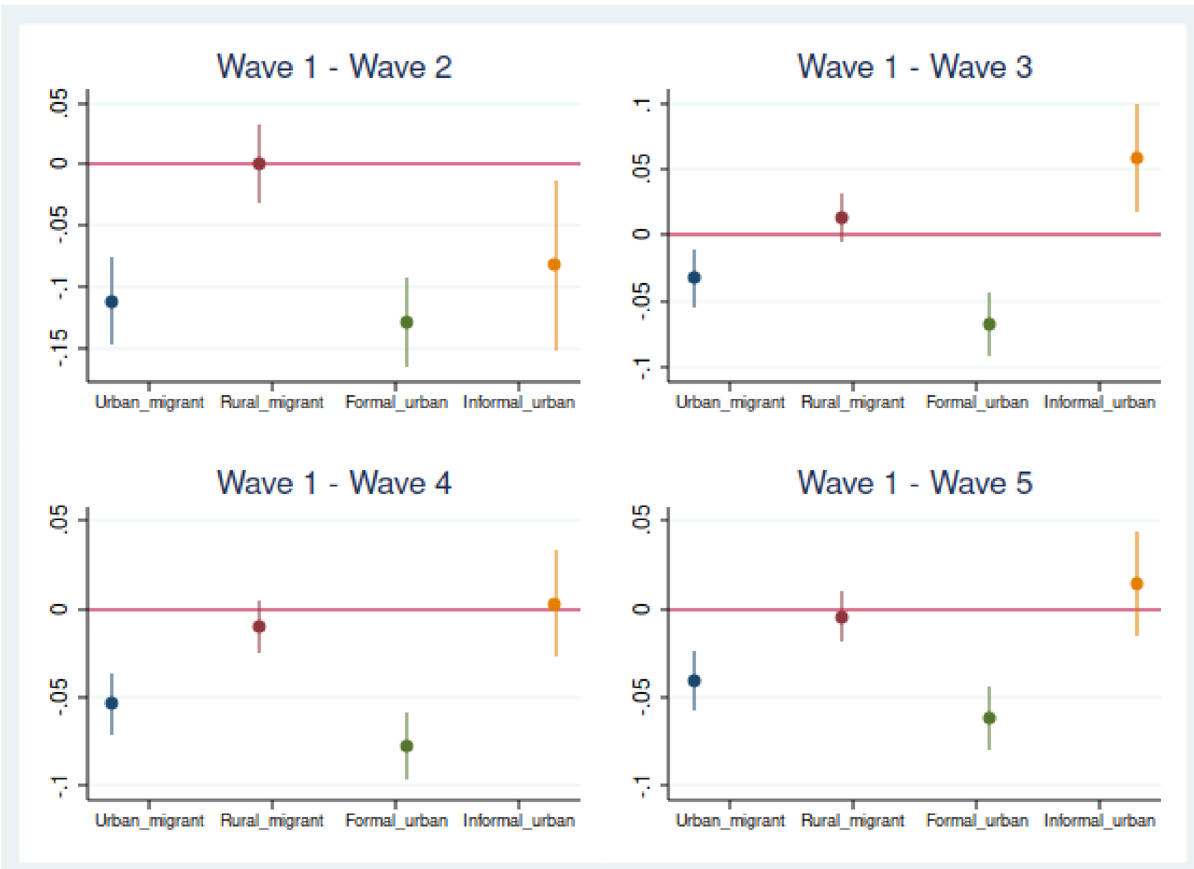
	(1)		(2)		(3)		(4)		(5)		(6)	
	Non migrants W1		Migrants W1		Diff(1-2) W1		Nonmigrants W5		Migrants W5		Diff(4-5) W5	
	mean	sd	mean	sd	b	t	mean	sd	mean	sd	b	t
MEPI H0 (k=33.3%)	0.52	0.50	0.50	0.50	0.02	(1.51)	0.21	0.41	0.13	0.34	0.08***	(8.43)
MEPI counting vector	0.35	0.36	0.35	0.37	0.01	(0.54)	0.13	0.26	0.08	0.23	0.04***	(6.86)
No mod. cooking fuel	0.58	0.49	0.55	0.50	0.03*	(2.22)	0.32	0.46	0.12	0.32	0.20***	(20.48)
No mod. lighting	0.35	0.48	0.37	0.48	-0.02	(-1.71)	0.10	0.30	0.08	0.27	0.02*	(2.30)
No elec. access	0.35	0.48	0.37	0.48	-0.02	(-1.52)	0.17	0.37	0.14	0.34	0.03***	(3.49)
No mod. stove	0.49	0.50	0.49	0.50	-0.00	(-0.10)	0.19	0.39	0.13	0.34	0.06***	(6.28)
No cell or tell	0.22	0.41	0.21	0.41	0.01	(1.00)	0.08	0.28	0.10	0.30	-0.02*	(-2.15)
No radio or TV	0.19	0.39	0.18	0.39	0.00	(0.48)	0.13	0.33	0.17	0.38	-0.04***	(-4.33)
Log(per cap HH exp)	6.13	0.77	6.11	0.75	0.02	(0.92)	6.28	0.77	7.06	0.92	-0.78***	(-33.61)
hhsize	6.30	3.32	6.26	3.05	0.04	(0.44)	6.68	3.82	3.54	2.72	3.14***	(39.18)
educ	4.25	4.26	6.54	4.25	-2.29***	(-20.41)	7.13	4.11	9.69	3.38	-2.57***	(-27.13)
age	26.45	22.01	17.49	12.20	8.97***	(22.14)	35.52	21.98	26.61	12.17	8.92***	(22.05)
female	0.58	0.49	0.51	0.50	0.07***	(5.67)	0.58	0.49	0.51	0.50	0.07***	(5.67)
female_head	0.57	0.50	0.57	0.49	-0.01	(-0.40)	0.72	0.45	0.55	0.50	0.17***	(13.05)
head_educ	4.25	4.25	4.70	4.44	-0.46***	(-3.74)	5.46	4.53	9.60	3.80	-4.14***	(-38.91)
child_share	0.50	0.21	0.53	0.20	-0.03***	(-5.63)	0.44	0.22	0.28	0.28	0.16***	(22.64)
Observations	5524		1946		7470		5524		1946		7470	

Notes: The table presents wave one and wave five averages of outcome and control variables for migrants and non migrants. Columns 3 and 6 present differences in the means of each variable as well as t-stats associated with a test for the differences in means, for Wave 1 (before migration) and Wave 5 (after migration), respectively. *Source:* Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017)

6.1 Difference in differences results

Table 9 presents DiD coefficients distinguished by the migration destination. These coefficients are also plotted in Figure 6. Regressions are run for i) rural-urban migrants (without distinguishing between formal/informal destination, ii) rural-rural migrants (i.e. migrants moving to a different rural area), iii) rural-formal urban migrants (moving into a formal urban house) iv) rural-informal urban migrants (moving into a free standing or back-yard shack). Across all specifications, we observe that migration is correlated with a 3-15 point decline in energy poverty as measured by the MEPI counting vector (which ranges between 0 and 1). The results also suggest additional gains in energy access from migrating to an urban area are driven by migrations to formal housing in urban areas and that from an energy-access perspective, migrants to informal urban housing do not experience additional gains relative to respondents who remained in rural areas.

Figure 6: DiD Regression coefficients.



Source: Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017) *Notes:* The figure presents coefficient plots of the DiD interaction terms for regressions of MEPI deprivation scores for rural-urban migrants, rural-rural migrants, rural-formal urban migrants and rural-informal urban migrants, for various time periods after wave 1. Negative coefficients indicate relatively more rapid declines in this measure of energy poverty compared to rural stayers. The comparison group for each regression period is respondents who remain in the same rural households for the entire period. Rural-urban migrants are matched to observationally similar non-migrants, based on a series of control variables, including baseline per capita expenditure, education, household head age and gender, baseline marital status, population group, baseline household size and child share and baseline province. This is carried out using the Stata "Diff" command (Villa, 2019).

Table 9: Propensity score DiD regression coefficients

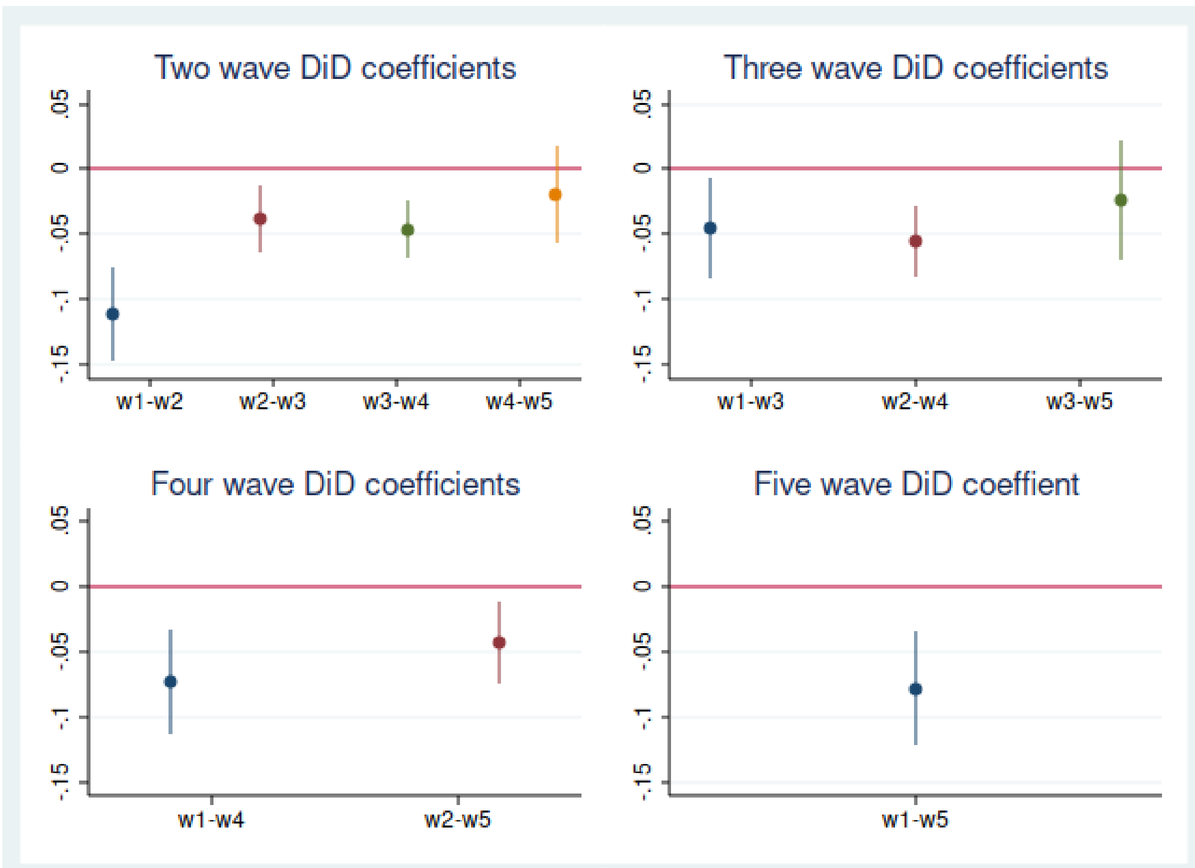
	(1) Rural-urban	(2) Rural-Rural	(3) Rural-formal urban	(4) Rural-inf. urban
DiD W1-W2	-0.111***	0.000703	-0.129***	-0.0820**
	(0.02)	(0.02)	(0.02)	(0.04)
Observations	20252	20390	20050	19778
R^2	0.071	0.006	0.125	0.050
	(5) Rural-urban	(6) Rural-Rural	(7) Rural-formal urban	(8) Rural-inf. urban
DiD W1-W3	-0.0323***	0.0129	-0.0672***	0.0588***
	(0.01)	(0.01)	(0.01)	(0.02)
Observations	18484	19524	17964	17050
R^2	0.071	0.038	0.107	0.033
	(9) Rural-urban	(10) Rural-Rural	(11) Rural-formal urban	(12) Rural-inf. urban
DiD W1-W4	-0.0539***	-0.0101	-0.0778***	0.00281
	(0.01)	(0.01)	(0.01)	(0.02)
Observations	16506	18082	15508	14156
R^2	0.118	0.076	0.153	0.084
	(13) Rural-urban	(14) Rural-Rural	(15) Rural-formal urban	(16) Rural-inf. urban
DiD W1-W5	-0.0407***	-0.00460	-0.0621***	0.0140
	(0.01)	(0.01)	(0.01)	(0.02)
Observations	14492	16672	13408	11870
R^2	0.155	0.123	0.185	0.124

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, ***

Source: Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017). *Notes:* The dependent variable in all cases is the logged uncensored MEPI counting vector, a weighted sum measuring in how many components of the MEPI individuals are deprived of energy access in. As such, negative coefficients indicate relatively more rapid declines in this measure of energy poverty compared to rural stayers. The comparison group for each regression period is respondents who remain in the same rural households for the entire period. Rural-urban migrants are matched to observationally similar non-migrants, based on a series of control variables, including baseline per capita expenditure, education, household head age and gender, baseline marital status, population group, baseline household size and child share and baseline province. This is carried out using the Stata "Diff" command (Villa, 2019).

Figure 7 restricts the analysis to mono-directional migrations and differentiates the results by the time after migration. For example, the top left panel of 6 presents DiD regression coefficients for all wave-to-wave migrations. The top right panel presents results for different samples that span three waves (i.e. rows 8,9 and 10 in 7. There appears to some increase in the gains from migration as the time after migration increases.

Figure 7: DiD Regression coefficients.



Source: Own calcualtions using SALDRU (2008, 2010, 2012, 2014, 2017) *Notes:* The plotted coefficients correspond to DiD interaction coefficients for migrants as specified in rows 5-13 of Table 7. The figure presents coefficient plots of the DiD interaction terms for regressions of MEPI deprivation score at various stages after migration. This is carried out using the Stata "Diff" command (Villa, 2019).

6.2 Robustness

Table 10 presents regression results where the comparison group of rural stayers is restricted to respondents who *would* themselves migrate later on in the panel, but had not yet migrated at the end-line period in the DiD estimation. As such, we compare pre-and post migration outcomes amongst a set of respondents who all would take the decision to migrate to an urban area, but do so at different times. We find the coefficients are virtually unchanged from those in Table 9.

Table 10: Propensity score DiD - late migrants as control group

	(1) W1-W2 estimate	(2) W1-W3 estimate
Wave 2	-0.0411***	
	(0.01)	
Migrant W1-W2	0.00780	
	(0.02)	
DiD	-0.110***	-0.0306*
	(0.02)	(0.02)
Wave 3		-0.104***
		(0.01)
Migrant W1-W3		-0.000326
		(0.01)
Constant	0.301***	0.289***
	(0.01)	(0.01)
Observations	3204	3584
R^2	0.066	0.071

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Here the non-migrant 'control' group is restricted to rural residents who would themselves migrate later on in the panel. *Source:* Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017)

7 Discussion and Conclusion

Our results present what is, to our knowledge, a first analysis of the returns to internal migration in terms of energy poverty in Africa. We use a panel data set in which we are able to track energy outcomes of both migrants and non-migrants over a ten year period. In particular, we find that despite service-delivery challenges facing many local municipalities, and indeed rural-urban migrants themselves, there exist clear gains in energy access from migrating to urban areas for the majority of individual migrants themselves. These gains should be seen in addition to gains in per-capita expenditure experienced by individual migrants found by Garlick et al. (2016). Garlick et al. (2016) find that households that 'receive' a new migrant experience a drop in overall per-capita income. Although we have not explicitly explored the implications for households that receive a migrant, it is unlikely that energy access would result in the same type of trade-off, given that major gains in energy access are driven by changes in cooking fuels towards grid electricity, which is largely a supply side issue. Our results should be seen as an addition to the literature focusing on understanding the implications of urbanization in South Africa.

A key mechanism driving energy poverty declines for migrants is a due to a difference in cooking fuel use between rural and urban areas. Rural residents are likely to have both the time and access to forest resources to collect wood and other traditional fuels. In urban areas, these resources are much more limited, necessitating a move "up the energy ladder" by switching to fuels such as electricity, paraffin/kerosene and gas in urban areas.

However, these gains from migration are driven by the improvements in energy access for those migrants who move into formal dwellings in urban areas. A substantial share (up to 30%) of new urban arrivals, move into some form of informal housing. One in five new urban arrivals is either living in freestanding or back-yard shack. For these migrants to informal urban areas, there are no clear additional gains in energy access. In this regard, back-yard shacks present an opportunity to improve safe energy access, due to their proximity formal homes with existing grid connections.

On the other hand, the results presented here also suggest that energy access is improving rapidly in rural South Africa, with relatively rapid increases in electrification and the spread of low-cost electrical appliances into rural areas. Indeed, given the large difference in the monetary poverty headcounts (a difference close to 25%) between rural and urban areas, one might expect for there to be larger differences in energy poverty. Encouragingly, energy poverty has not been as stagnant as monetary poverty in South Africa. This also reiterates the point that a reliance on monetary measures alone hides changes in other aspects of well-being. Energy poverty reductions as a result of internal migration may be even more pronounced in other some African countries, where rural electrification is taking place at a much slower pace (Bernard, 2012) .

We also provide evidence of the scale of rural-to-urban migration taking place. Roughly one in five (18%) of NIDS rural residents in 2008 would be observed to migrate to an urban area (and be resident there) at some point between 2008 and 2017. In addition, roughly 52% of individuals resident in rural households would be affected by out-migration of one or more household members to urban areas.

Cities make up to 80% of global GDP.[30] They are powerhouses of economic development, innovation and social progress. For many South Africans, urban areas represent the promise of a better future. von Fintel and Fourie (2019) for example show that rural-urban migration out of the former apartheid homelands is one of the key avenues of poverty reduction in the country in the democratic era. However, deep inequalities and service delivery challenges characterize South African cities and threaten the access to opportunities for the most vulnerable.

The upgrading of informal settlements is a difficult challenge and many households in informal settlements face a lack of access to water and sanitation, overcrowding and insecurity of tenure. Access to electricity is another factor of differentiation between formal and informal settlements. Our results suggest that energy access may be improving more rapidly in rural

[30]https://www.worldbank.org/en/topic/urbandevelopment/overview.

areas than in informal urban areas. The rate of new household formation in these areas as well as regulation limiting electricity supply to some informal areas due to safety concerns likely add to this.

Of course, this question cannot be divorced from the one on the transitory versus permanent nature of informal settlements. Recent evidence suggests that they tend to be of a more permanent nature, leading informal settlement dwellers to fall into poverty traps (Marx, Stoker, & Suri, 2013). Informal settlements being characterized by weak property rights, dwellers and utility providers have little incentives to invest into significant slum upgrading. As a matter of fact, informal settlements suffer from a so-called investment inertia and policy trap (see (Marx et al., 2013)).

Electricity access can deliver a wide range of economic and non-economic benefits to populations and has an important bearing on several factors influencing their well-being, such as economic welfare, improved quality of life, improved health, better educational prospects, and aspects of individual and collective time-use ((Jeuland et al., 2020; Bos et al., 2018; Bonan et al., 2017)). Under-investment from policy makers in electricity in informal settlements is and will continue to nurture social inequalities and economic inefficiencies. If cities are to continue to foster prosperity and social change, policy makers in South Africa and more generally around the Globe need to rethink their service delivery policies and place access to electricity at the core of their urban agenda.

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Appendix A:

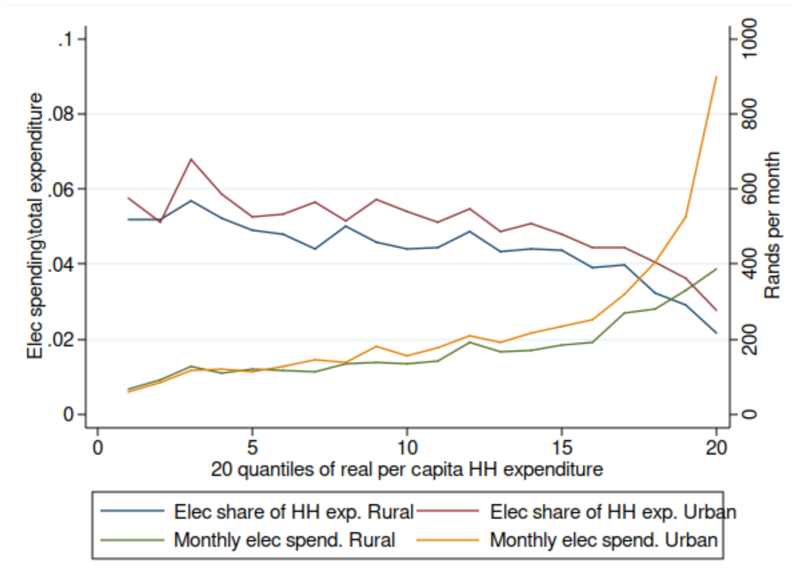
Table 11: Multidimensional Energy Poverty Index for South Africa, 2008-2017.

	MEPI Headcount		MEPI Intensity	
	mean	sd	mean	sd
Wave 1 (2008)	0.281	0.450	0.662	0.181
Wave 2 (2010)	0.215	0.410	0.669	0.192
Wave 3 (2012)	0.155	0.362	0.661	0.181
Wave 4 (2014)	0.122	0.328	0.651	0.191
Wave 5 (2017)	0.097	0.296	0.621	0.186
Total	0.171	0.376	0.657	0.186

Notes: K=33.33. The table presents mean MEPI headcount and intensity scores for all respondents in each wave of the NIDS panel.*Source:* Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017). Based on MEPI developed by Nussbaumer et al. (2012)

Appendix B:

Figure 8: Absolute and relative electricity spending in rural and urban areas, by expenditure ventile



Notes: Pooled NIDS sample. *Source:*Own calculations using SALDRU (2008, 2010, 2012, 2017, 2017).

Appendix C:

Table 12 presents Wave 1 logit regression results of individual and household level correlates with individual migration at any stage during the panel. These correlates motivate the inclusion of the control variables in the Propensity score matching difference in differences analysis.

Table 12: Logit regression - individual and household correlates with migration

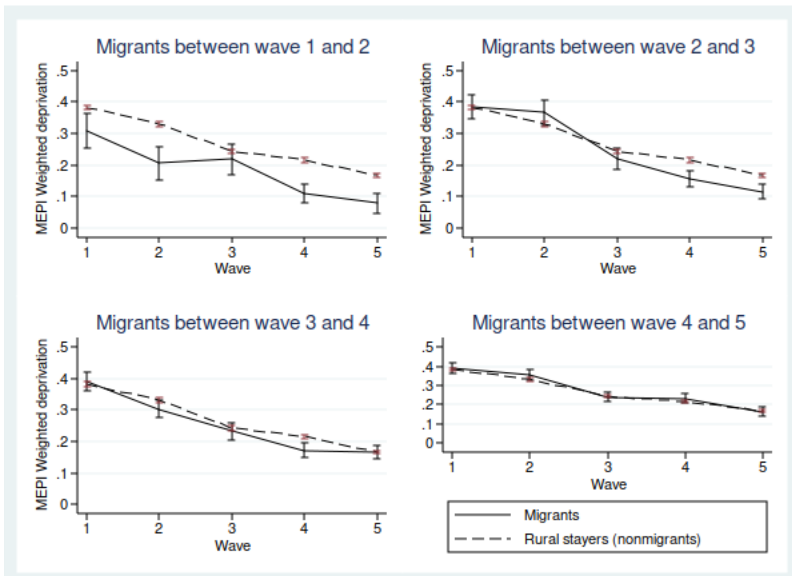
	Rural-urban migrant between W1 and W5
Yrs Education	0.191***
	(10.54)
Age	-0.0447**
	(-2.54)
Age squared	-0.0000149
	(-0.05)
Female	-0.134*
	(-1.88)
Female headed HH	-0.0554
	(-0.73)
HH receives child grant	0.0513
	(0.38)
Log per capita HH exp	0.0236
	(0.44)
Log MEPI counting vector	0.368**
	(2.07)
Pop group = coloured	1.330***
	(3.66)
Married	-0.341**
	(-2.34)
HHsize	-0.0262**
	(-2.06)
HH head education	-0.0215**
	(-2.35)
HH child share	0.835***
	(3.80)
EC	1.082***
	(2.60)
NC	0.388
	(0.96)
FS	1.345***
	(2.99)
KZN	0.244
	(0.59)
NW	0.579
	(1.35)
GP	1.164**
	(2.33)
MP	0.223
	(0.52)
LIM	0.639
	(1.53)
constant	-2.485***
	(-3.89)
N	6120

Notes: t statistics in parentheses. * $p < 0.10$, ** $p < 0.05$, ***. The regression is for Wave 1 rural residents and the dependent variable is an indicator of whether the respondent would migrate to an urban area at any stage from Wave 1 to Wave 5. As in the rest of the paper, the sample excludes white and Indian respondents.
Source: Own calculations using (SALDRU, 2008, 2010, 2012, 2014, 2017)

Appendix D:

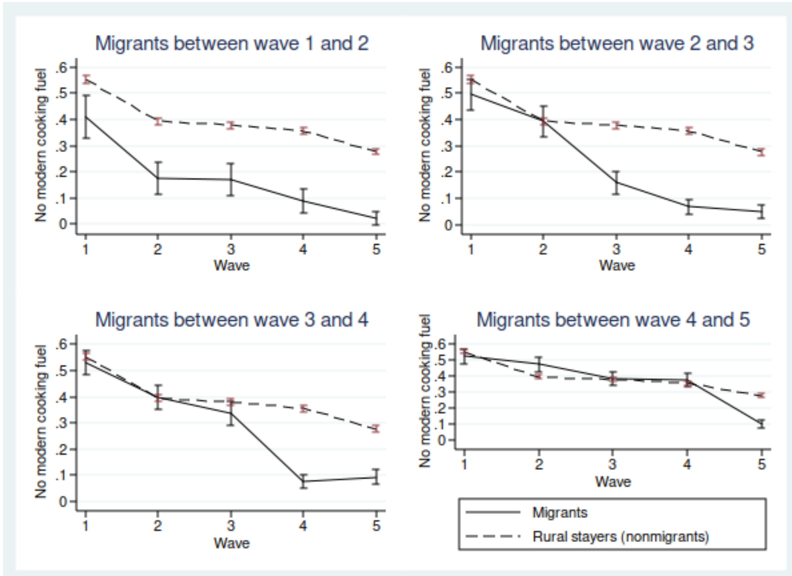
Figures 9 to 15 present pre-and-post migration trends for migrants and non-migrants for the uncencored MEPI counting vector as well as its constituent variables. The figures are means of the outcome variables tracked before and after migration takes place, plotted for a group of rural stayers who remain in rural areas throughout the panel, compared to 'mono-directional' migrants who left rural areas at various stages during the panel.

Figure 9: Mean MEPI deprivation score -migrants vs nonmigrants



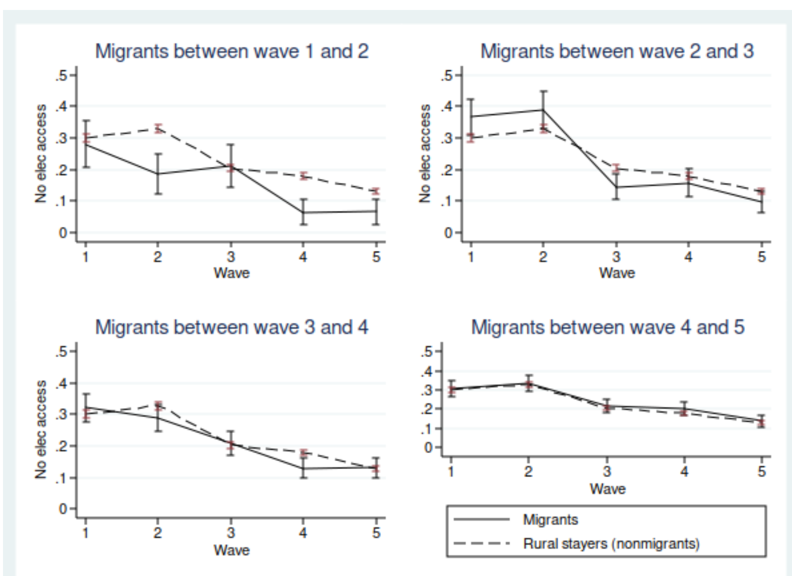
Source: Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017).

Figure 10: No modern cooking fuel -migrants vs nonmigrants



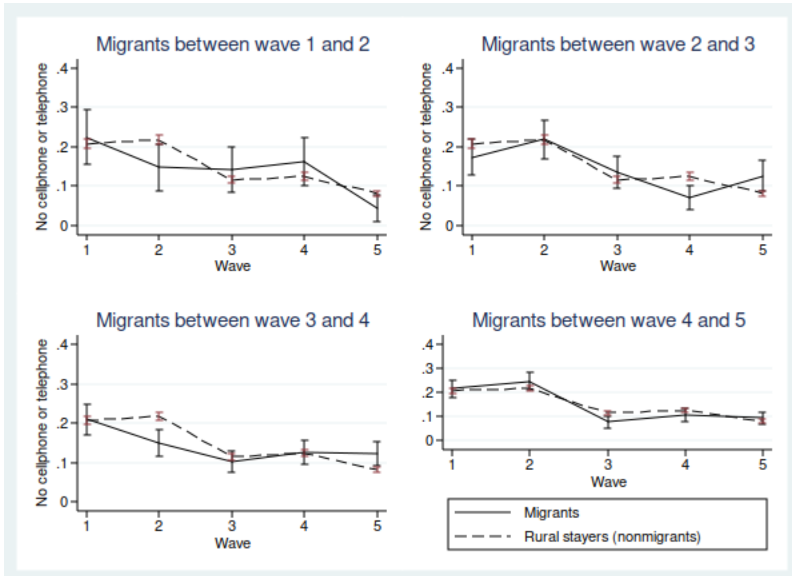
Source: Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017).

Figure 11: No electricity access-migrants vs nonmigrants



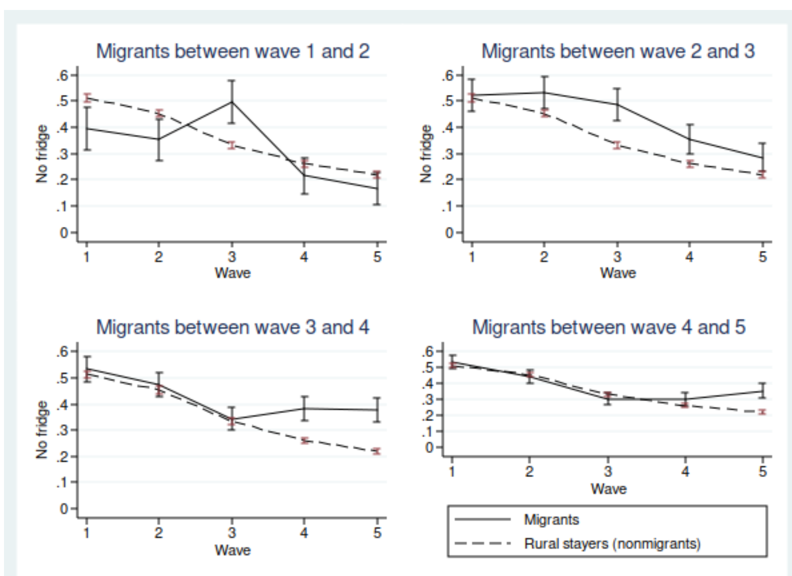
Source: Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017).

Figure 12: No cellphone or telephone -migrants vs nonmigrants



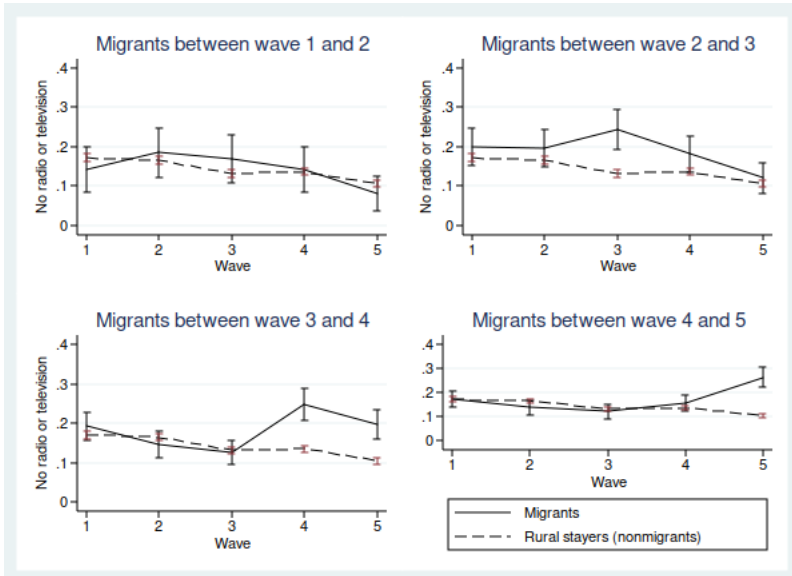
Source: Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017).

Figure 13: No fridge -migrants vs nonmigrants



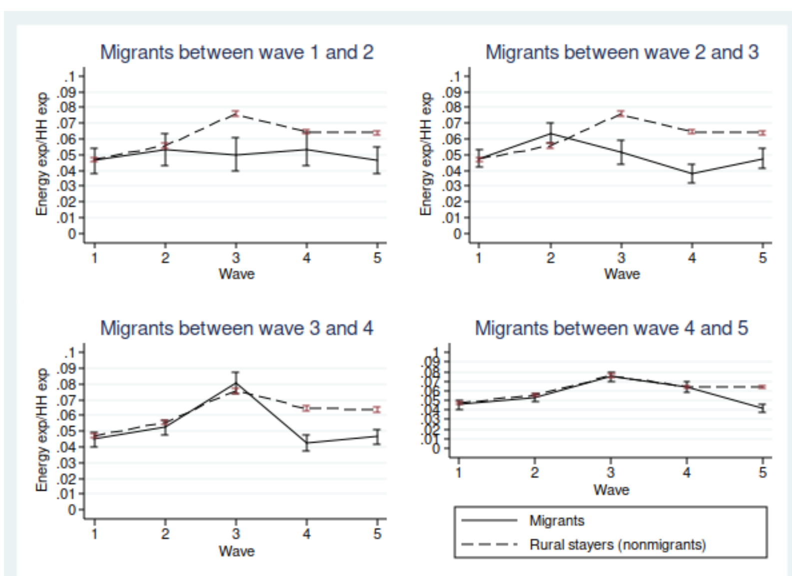
Source: Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017).

Figure 14: No radio or television -migrants vs nonmigrants



Source: Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017).

Figure 15: Ratio of energy expenditure to total household expenditure - Migrants vs non-migrants



Source: Own calculations using SALDRU (2008, 2010, 2012, 2014, 2017).

Appendix E:

Table 13: W1 and W5 summary statistics

	Wave 1 (2008)		Wave 5 (2017)	
	mean	sd	mean	sd
elec_access	0.814	0.389	0.897	0.304
light_mod	0.827	0.378	0.948	0.223
cook_mod	0.720	0.449	0.876	0.330
elec_gas	0.692	0.461	0.906	0.291
buy_elec	0.713	0.452	0.816	0.387
spend_elec	182.724	257.225	400.242	651.821
buy_other	0.338	0.473	0.274	0.446
spend_other	86.960	166.272	153.368	212.865
fridge	0.613	0.487	0.843	0.364
communication	0.828	0.378	0.930	0.254
infoacc	0.877	0.329	0.907	0.291
elec_stove	0.645	0.478	0.873	0.333
gas_stove	0.154	0.361	0.200	0.400
par_stove	0.281	0.450	0.179	0.383
energy_ratio	0.043	0.049	0.054	0.049
pchhexp_r_ln	6.879	1.249	7.144	1.208
female	0.516	0.500	0.511	0.500
female_head	0.442	0.497	0.574	0.494
age	26.940	19.331	28.314	19.595
agesq	1099.422	1366.470	1185.627	1413.065
educ	6.814	4.827	7.706	4.853
head_educ	7.511	4.745	9.092	4.239
employed	0.241	0.428	0.308	0.462
head_employed	0.426	0.494	0.472	0.499
married	0.273	0.445	0.744	0.436
child_share	0.401	0.246	0.362	0.252
N	28226		40943	

Source: Own calculations using SALDRU (2008, 2017) *Notes:* The table presents weighted summary statistics for the full NIDS sample in Wave 1 and Wave 5.