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Rethinking social change: Does the permanent and transitory effects of electricity and solid fuel use predict health outcome in Africa?

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ABSTRACT

One of the greatest global challenges of this 21st century is electricity deprivation, which involves extending access to electricity to hundreds of millions of people, while simultaneously trying to improve the quality of life and maintain their good health. Electricity deprivation combined with poor health systems and social circumstances can be a problem as it tends to expose the population to greater health risks. While the opponents of energy use almost never deny that electricity use is necessary for health, instead, they failed to admit that a lack of readily available electricity could mark the difference between life and death. This is because reliable electricity supply is required for basic socioeconomic needs such as home cooking and storage, water supply, lighting and reduction of indoor air pollution that may arise from solid fuel usage. This study examines the permanent and transitory effects of electricity and solid fuel use on health in Africa. The empirical strategy combines the van praag transformation and advanced econometrics based on Mundlak methodology. By using the Mundlak statistical procedure, the study breaks down the permanent and transitory effects of energy use (electricity and solid fuel use) on health. The study also corrects for potential endogeneity problem using the Hausman -Taylor statistical procedure. It further strengthened the analysis by correcting for cross panel correlation using the Feasible GLS methodology. The findings revealed that having access to electricity reduces health risks associated with burning solid fuels in Africa.

1. Introduction

This study examines the permanent and transitory effects of electricity and solid fuel use on health in Africa. The purpose of this research is to provide information to policymakers so that they can design a comprehensive social policy that promotes and maintains a healthy population while avoiding the negative effects of energy deprivation on future human development in Africa.

Poor access or fluctuation in electricity supply can encourage regular or continuous use of solid fuel (e.g., charcoal, dung, animal skin) (Velema et al., 2002; Zhang and Smith, 2007; Nawaz, 2021; Marcus, 2021). However, the concern is that smoke from solid fuel contains poisonous particles that can put the population at risk of indoor air pollution and could cause severe health complications (Mueller et al., 2011; Bridge et al., 2016; Churchill and Smyth, 2021; Acheampong et al., 2021a, b; Shobande, 2020a). While a frustrated and desperate electricity-deprived population is unlikely to consider the cumulative health effects of using solid fuel, it is critical to investigate the permanent and transitory effects of usage of electricity and solid fuel on health. Such an investigation is vital to provide relevant authorities with a clearer understanding on the mechanisms by which electricity and solid fuel affect health and assist in designing a sustainable energy policy that can help maintain and prolong health of African population.

Faster progress towards universal and efficient energy access will require a proper understanding of the transitory - permanent effects of electricity and solid fuel usage on health in Africa. The transitory component has several features that reflect the effect of unexpected fluctuation or unstable electricity on health. For example, a major electrical failure due to operational problems or lightning strikes at the hospitals can lead to death of patient in need of intensive care. Fluctuating or unstable electricity supply can expose the older population to health complications or people suffering from co-morbid condition that requires air conditioning to survive (Shobande, 2020a; Churchill, 2021; Acheampong et al., 2021a; Mishra, 2003). Fluctuations in electricity

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supply can have a transitory effect on public health and health care delivery. For example, severe power outages can trigger hospital overcrowdings, where emergency rooms would be overflowing with people seeking electricity for medical equipment. This can result in health complications and, in extreme case, death (Ahmad et al., 2014; Banerjee et al., 2021; Nawaz, 2021; Shobande, 2019). Also, inadequate electricity supply can hinder the effective treatment of diseases (e.g., diabetes, tuberculosis, and respiratory diseases) (Churchill and Smyth, 2021; Nawaz, 2021; Marcus, 2021).

The lack of electricity leads to an efficient use of life saving hospital equipment (e.g., ventilators, oxygen conservers, and essential drugs), thereby increasing incidental mortality that could have been avoided. Electricity deprivation extends beyond the hospital scales as African people heavily rely on solid fuels for cooking, and lightening. Food is often spoiled without electricity to power refrigerators (Nawaz, 2021; Banerjee et al., 2021). The consequence of unreliable electricity supply often leads to a sustained use of solid fuel. For example, due to a lack of electricity, many African homes use solid fuels for heating, which has a detrimental effect on health of the population. A report by WHO (2019) has shown that 90 % of the African population relies on highly polluting energy sources for cooking and lighting (i.e., charcoal and animal waste). This can result in severe health complications. A report by World Energy Council (2019) has shown that highly polluted energy use accounts for 1.5 million deaths annually in Africa.

The permanent component refers to factors that determine the future health behaviour of a population. The choice of energy use on health depends on availability, affordability, willingness to pay and expected health benefits. Permanent impact of energy-health problem can also arise from gaps in demand and supply. First, energy deprivation can hinder opportunities to generate more income, which are required to improve the population's standard of living and preserve health (Sagar, 2005; Elias and Victor, 2005; Nawaz, 2021; Acheampong et al., 2021a; Etienne et al., 2011). many African people cannot afford to pay connection fees and electricity bills because of low and irregular income. For example, power outages have become prominent feature of health centres in remote areas (rural and islander). Many island and rural communities residing in remote areas face blackouts because of the difficulties in accessing electricity; consequently, these people depend on solid fuel for usage. Also, many people with a low-income which cannot afford electricity bills are motivated to use solid fuel. While solid fuel uses are available, and affordable, they are not without indoor air pollution risk. Indoor air pollution from solid fuel causes permanent health conditions in children, older adults, and people with chronic diseases (Shobande, 2020a; Shobande and Asongu, 2021). Indoor air pollution is linked to permanent health conditions, for example, like Asthma, stroke, heart diseases. Possibly, a comprehensive rural and off grid electrification schemes could help reduce the socioeconomic hardship and improve the health of the population.

Second, electricity deprivation is associated with worsening disruptions in the water supply which affect health. For example, erratic electricity supply can disrupt the water access and expose populations to numerous health-related risks due to polluted water use (Marcus, 2021; Acheampong et al., 2021b; Nawaz, 2021). Studies including that by Nawaz (2021) and Marcus (2021) have argued that deaths resulting from adverse environmental conditions due to a lack of safe water could have been averted if electricity were available. This is consistent with reports that the availability of water in Africa has been hampered by the lack of electricity, which could explain the rising mortality cases in the region (Fankhauser and Tepic, 2007; Herrero and Ürge-Vorsatz, 2012; Bonan et al., 2017; Shobande, 2020b; Asongu et al., 2020).

Third, health access is a key determinant of health. This implies that low health expenditure and unstable electricity supply can be an important factor for prolong and healthy population. Currently, Africa's health spending is relatively low compared to other parts of the world. Nearly, 60 % of deaths in Africa can be avoided if the government could be persuaded to increase health spending and reassure stable electricity supply (Shobande, 2020a, b; Acheampong et al., 2021b). The public healthcare is suffering from chronic shortage of medicine. Clearly, majority of excess mortality recorded in Africa has been linked to lack of medicines for patient.

This study improved upon previous studies by Bridge et al. (2016), Banerjee et al. (2021) and Acheampong et al. (2021a) and examines permanent and transitory effect of electricity and solid fuel use on health. It investigates a panel of 29 African countries for the period of 1990 to 2015. The empirical strategy follows the transformation proposed by van Praag et al. (2003), which allows the decomposition of the component of electricity and solid fuel into permanent and transitory effects. Four advanced econometric methodologies are used. The analysis begins by exploring the standard panel fixed effect (FE) specification which assumes that unobserved state specific component of the error term, has a fixed relationship with dependent variable. However, there are two immediate challenges with the standard FE methodology, notably: (a) the assumption of a state fixed effect, which is unlikely to be case, and (b) the time invariant effect is subsumed, making it difficult to assess the permanent and transitory effects. To address this concern, the dynamic empirical strategy by van Praag et al. (2003) is used to decompose the effects into the permanent and transitory impact, into a single equation. It then utilises an econometric approach by Mundlak (1978), to analyse and make inference on the permanent and transitory effects of electricity and solid fuel on health. The potential problem of endogeneity is settled by using the statistical procedure of Hausman and Taylor (1981). Furthermore, the analyses are strengthened by correcting for cross-panel correlation using the Feasible Generalised Least Squares (FGLS) estimator.

The empirical results provide three important conclusions. First, the results show a strong negative relationship between electricity use and overall mortality. Specifically, the results show that the permanent effect of electricity use is predicted to reduce the mortality. Second, there is strong evidence to suggest that a permanent increase in solid fuel usage increases mortality rate. Third, the channel through which electricity can affect health, has been identified as indoor air pollution. This finding is of interest not only because they provide a fresh insight into the determinant of health, but because they suggest that permanent electricity use can lower mortality and improved the health of the population in Africa.

The contributions of this research are threefold. First, it develops and tested several hypotheses on the permanent and transitory effects of electricity consumption and solid fuel use on health in Africa. Existing research is generally limited to household data, and relative exceptions using panels are of interest in the developed economy (Ahmad et al., 2014; Oum, 2019). Consequently, international evidence focusing on African is still absent in the literature. This research fills in the gaps and offers new perspectives that can assist policymakers in developing a comprehensive energy policy to address the African continent's energy and health woes. Second, it empirical dissect predicts, and makes precise inference on the relationship between energy and health using statistical driven procedure based on the Mundlak methodology. Furthermore, it corrects for cross panel correlation using the Feasible GLS estimator. Third, the research directly speaks on the public debate on the choice of energy and how it affects health of the population and provides a foundation for a fresh dialogue on urgent needs for electrification of Africa as a solution to their socioeconomic problem.

The remainder of paper is organised as follows: Section 2 provides a comprehensive literature review. It discusses the theoretical empirical literature, set the research questions and formalised three prominent hypotheses, Section 3 presents conceptual framework on the relationship between energy and health. Section 4 describes the data and research methodology. Section 5 presents the empirical results, discusses the findings, and underscored the research contributions. Section 6 concludes with policy recommendations.

2. Literature review

This section presents a concise theoretical and empirical literature with the recognition of scholarly contributions as well as the strengths, flaws of their findings, and hypotheses development.

2.1. Theory and empirical review on the effects of solid fuel use on health

Cooking and heating using solid fuels such wood, charcoal, crop residues and animal dung is possibly the most indoor air polluting energy sources in developing countries (Smith et al., 2004; Mehta et al., 2006). Some studies have shown that the practise of burning of solid fuels in inefficient stoves for cooking and space heating with poor ventilation, can result in significant health risks, especially among those without access to electricity (Mehta and Shahpar, 2004; Smith et al., 2004; Torres-Duque et al., 2008). Some studies found that cooking with solid fuel, especially if unvented, can raise indoor nitrogen dioxide levels, causing in air pollution (Bonjour et al., 2013; Bridge et al., 2016; Churchill and Smyth, 2021; Acheampong et al., 2021a, b; Nawaz, 2021).

In fact, Bonjour et al. (2013) used a multi-level model and national survey data from 1980 to 2010, to analyse the health risk from solid fuel, using indoor air pollution as a mediating factor. They reported that solid fuel use is threatening the health of African and South Asian populations. Some studies suggested that the people who rely on solid fuel have a higher risk of dying from acute respiratory diseases (Velema et al., 2002). Pokhrel et al. (2015) examined the health effects of indoor air pollution from four different cooking fuels and identified fine particulate (PM $_{2.5}$) as a major health threat associated with solid fuel uses. Quansah et al. (2017) explored the effectiveness of interventions to reduce household indoor air pollution and improved health in home from solid fuel in low- and middle-income countries. They reported that exposure to PM $_{2.5}$ associated with solid fuel use, endangered the health of the population.

Mehta and Shahpar (2004) assessed the health benefits of reduced indoor air pollution from solid fuel use in Africa, South and Southeast Asia and the Americas, using the generalised cost effectiveness methodology. They considered three main scenarios, notably: (a) providing access to clean fuel; (b) providing improves stoves; and (c) providing the population with clean fuel and stoves. Their study identified two health outcomes linked with indoor air pollution from solid fuel usage. It included respiratory diseases in younger people and chronic pulmonary diseases in adults of over twenty years. They also showed that using solid fuels is cost-effective, but it causes indoor air pollution, which is poisonous, explosive, and may lead to cancer.

2.2. Theory and empirical review on the effect of electricity uses on health

In contemporary literature, two important sets of theoretical and empirical papers are often discussed on the effects of electricity and solid fuel use on health. The first theoretical and empirical survey uses generalised method of moment (GMM) and is presented by (Hanif, 2018; Rasoulinezhad et al., 2020). Rasoulinezhad et al. (2020) examines the mortality effects of fossil fuel consumption in the Commonwealth of Independent States (CIS). It used the Generalized Method of Moments (GMM) for the period of 1993 to 2018 and reported that fossil fuel use, affects mortality through cancer and chronic respiratory disease. Their results added to the current literature by demonstrating how electricity deprivation could affect health through chronic respiratory disease and cancer. Hanif (2018) is another example of study on the impact of fossil fuel consumption on human health. The author implemented a generalised method of moment (GMM) using variables such as mortality measures, fossil fuel consumption, and solid fuel consumption for a panel of 34 middle- and lower-income countries for the period 1995–2015. Furthermore, the author reported that fossil fuel use, has an adverse effect on mortality, and the main channel of occurrence tends to be tuberculous. Thus, both studies are relevant, but the present focus on Africa.

The second study focuses on the time-based health effect of electricity consumption and solid fuel energy use and appraises their contributions and shortcomings. For example, Gohlke et al. (2011) estimated the global public health effects of electricity consumption and coal consumption. Their study developed and implemented an autoregressive model for a panel of 41 countries, with different development paths and using time series data between 1965 and 2005. Their results suggested that improving electricity consumption was associated with lower mortality outcome but found inconclusive evidence for coal consumption. Another related time-series study by Al-Mulali (2016) on the bidirectional long-run relationship between energy consumption and life quality in 198 countries between 1990 and 2009. They employed canonical cointegrating regression (CCR). The results revealed that electricity consumption improves the health of 70 % of the countries despite their different incomes. Using canonical cointegration regression, Youssef et al. (2016) investigated the causal link between energy consumption and health outcome for a panel of 16 African countries for the period of 1971 to 2010. They reported an improved energy consumption as a long-run relationship with a lower health outcome. This group of studies has contributed to the literature by explaining two ways in which electricity use can have an impact on health.

Banerjee et al. (2021) assessed the effect of energy poverty on health and education outcome for the period of 1990 to 2017, for 50 developing countries and within four different regions, including Africa, Asia, Europe, as well as Latin America. The dependent variable used was various indicators of health (e.g., mortality, life expectancy) and education. The independent variable used is the energy development index (EDI), access to electricity, and total energy use measures. Other control variables used were urban population growth, institutional quality, higher corruption, and political instability. They used the standard FE and panel threshold regression methodology and reported that an increase in electricity access, positively influences life expectancy. Furthermore, an increase in marginal effects of EDI on infant mortality is more beneficial to the least poor countries or higher per capita income countries when it comes to reducing infant mortality.

Acheampong et al. (2021a, b) observed the effect to access to electricity and clean energy on human capital development, in 79 energy poor regions throughout South Asia, sub–Saharan Africa, and Caribbean Latin America, and this for the period of 1990 to2018. Using the Lawbel two stage least square approach to address the issue of potential endogeneity, they reported that access to electricity negatively influences life expectancy, infant mortality, and maternal mortality. The possible explanation for the results by the authors was due to low usage of clean energy cooking technologies in the energy poor countries. It further indicated an overreliance on inefficient and solid fuels, which poses severe risk on the health of the population.

Evidently, the above recent works conducted by Gohlke et al. (2011), Bouzarovski and Petrova (2015a, b), Al-Mulali (2016), Youssef et al. (2016) and Qu et al. (2017) have provided the environmental and energy community with important findings concerning the detrimental effects of electricity deprivation on health. These findings have serious implications for public health and deserve a closer scrutiny. Thus, investigating the energy use in Africa and public health dilemma is crucial since none of the existing research looked specifically at the transitory and permanent effects of electricity and solid fuel use on health. Therefore, the lack of consensus and the plethora of different outcomes based on different theories, justify the need to investigate this aspect further.

2.3. Summary of the review

Electricity has become an unavoidable necessity to boost economic activity and promote human well-being. This is because modern economies rely on a regular electricity supply to carry out everyday activities. So far, researchers have attempted to investigate the relationship between energy use and health, but the results are mixed. However, the literature review has identified some ways through which energy deprivation can impact health.

These are mainly:

(a) Poor living conditions arising from cooking and heating impediments, poor access to a clean water supply, thermal discomfort in homes, poor ventilation, dampness, and exposure to indoor air pollution.
(b) Poor access to health services caused by shortages of power needed to preserve and utilise medical equipment as well as manage severe health conditions, exposure to health risks, and mental illnesses.
(c) Social deprivation generated by low standards of living and low productivity due to a lack of electrical power, stigma, and changes in health behaviour.
(d) Overall, energy deprivation results in critical health problems for both the younger and older generations; policymakers need to promote strong policies to improve population health.

Following the theoretical and empirical review, the relationship between energy use and health can be summarised with two general topics. The first topic examines the effects of energy use on health using macroeconometrics, but its findings are conflicting. For example, Acheampong et al. (2021a, b) showed that access to electricity and clean energy improves population health in the Caribbean, Latin America and sub-Saharan Africa but worsens population health in South Asia. In contrast, Banerjee et al. (2021) evaluated the link between energy poverty, health, and education for 50 developing countries; they affirmed that lower energy poverty is associated with higher health and education levels. Some studies have also identified standard of living as an area in which energy deprivation can affect population health (Churchill and Smyth, 2021; Pan et al., 2021; Ballesteros-Arjona et al., 2022; Asongu and Le Roux, 2017).

The second topic examines the impact of energy use on health using microeconometrics and reported mixed findings. Nawaz (2021) showed the relationship between energy poverty, climate shock, and health using a multidimensional index and highlighted the adverse effects of energy shortages on health in Pakistan. Abbas et al. (2021) confirmed that lack of power has an impact on literacy and access to clean water supplies and could potentially affect health in six Asian countries. Oum (2019) showed that a considerable percentage of Laotian homes rely primarily on fuelwood, which worsens living conditions, increases exposure to interior air pollution, and influences health behaviour and also observed that increasing access to electricity could reduce the health risks associated with indoor air pollution exposure in Lao People's Democratic Republic. While the mentioned findings on how energy use affects health are intuitively appealing, research exploring the long-term and short-term consequences is still missing. Hence, our research seeks to fill this gap by studying the permanent and transitory effects of electricity and solid fuel use on health in Africa.

2.4. *Justification for the choice of African continent*

This research focused on Africa and is motivated by four major factors. First of all, recent reports have shown that access to electricity is important for preserving a healthy population (WHO, 2018). For example, the WHO (2019) revealed that electricity deprivation accounts for 70 % of health complications and can lead to major public health crises. The report further agreed that Africa is more likely to be highly vulnerable due to its energy poverty, coupled with a poor public health situation (WHO, 2019). A similar report has shown that 90 % of the African population relies on highly polluting energy sources for cooking and lighting (i.e., charcoal and animal waste), resulting in severe health complications and reductions in productivity (WEO, 2017). Likewise, reports by WEC (2020) and WEO (2017) have shown that highly polluted energy use accounts for 1.5 millions of premature deaths annually, and Africans top the regional distribution of these premature deaths (WHO, 2018). Furthermore, energy deprivation in Africa hinders opportunities to generate more income, which are required to improve the population's standard of living.

Several reports have linked the increase in mortality to solid fuel usage. For example, WEC (2020) revealed that combustion solid fuel energy is a major source of indoor pollution, and this effect can lead to death-related diseases (i.e., chronic respiratory infection, lung cancer, asthma, and heart-related diseases). Millions suffer from lung and chronic respiratory infections due to traditional energy use (Qu et al., 2017; Bouzarovski and Petrova, 2015a, b; Shobande, 2020b). A recent report revealed that people are likely to be exposed to the greatest health risk from polluted energy, and over seven million infants and children under five years of age are likely to be affected (WHO, 2019). Likewise, a few studies have attributed the prevention of the functioning of many healthcare facilities to high pollution resulting from electricity deprivation, making it difficult to preserve human health and save lives in the region. For instance, WHO (2009) suggested that over 50 % of vaccines are wasted annually owing to poor electricity supply, and the majority are linked to the African continent). Several studies have also shown that many patients with severe complications are left to die from serious health complications because of a lack of electricity to perform critical diagnosis, and unfortunate patients are treated by candlelight by health providers (WHO, 2013; Bhatia and Angelou, 2014; Kanyangarara et al., 2017).

2.5. *Research questions*

At best, the empirical review on the effects of electricity deprivation on health has elicited conflicting reaction among researchers and policymakers. However, the findings remain inconclusive and equivocal. Similarly, a strand of literature focusing on the permanent and transitory effect of electricity and solid fuel uses on health has been overlooked.

In this research, we ask the following questions:

(1) What are the permanent and transitory effects of electricity on health?
(2) What are the permanent and transitory effects of solid fuel on health?
(3) How are the above effects differ between the (1) and (2) on health?

2.6. *Research hypotheses*

We address these questions by first formalising three prominent hypotheses on the permanent and transitory effects of electricity and solid fuel uses on health.

Hypothesis 1. There are no permanent and transitory effects between electricity use and health.

Hypothesis 2. There are permanent and transitory effects between solid fuel use and health.

Hypothesis 3. The permanent and transitory effects of electricity and solid fuel use differs greatly on health.

Testing these hypotheses has important implications for the policies needed to address Africa's electricity deprivation. Firstly, the evidence from the two sets of empirical studies reviewed above is still inconclusive, making it difficult for policymakers to provide appropriate responses to electricity deprivation, particularly in Africa. Secondly, the existing literature is still limited since it does not reflect the permanent and transitory impact of energy use on health. Thus, the study aims bridges this gap by investigating the transitory and permanent effects of electricity and solid fuel use on health in Africa. This is crucial since a proper understanding the permanent and transitory components can be resourceful for formulating policies, which help in realising the objectives of the Sustainable Development Goals (SDGs). Secondly, some of this previous research have serious shortcoming because they failed to properly control for endogeneity and cross panel correlations. This study addresses the problem (endogeneity and cross panel correlations), by using advanced econometric based on the Mundlak (1957) methodology, Hausman – Taylor (1981) and Feasible GLS estimator. Moreover, this study provides new information on the health risks associated with energy deprivation, which will improve the existing strategy used in combating indoor air pollution. Finally, testing the hypothesis is justified because relevant authorities need a clear understanding of the mechanism to formulate appropriate policy towards addressing the energy and health problem in Africa. Besides, this knowledge can help support a healthy population and enhance opportunities by improving productivity.

3. Conceptual framework

From the hypothesis (1–3), the permanent and transitory effects of electricity and solid fuel use on health can be specified as follows. Health is expressed as a function of energy use (electricity and solid fuel use), and income per capital while controlling for confounders.

$$H = h(E, I, X) \tag{1}$$

where H is denotes health, E denotes energy uses (electricity consumption (electricity) and solid fuel (solid)), I is the income per capita and X is a vector of other covariates or relevant variables that affects health such as improve water access, education, health expenditure, and indoor air pollution.

There are two types of energy use considered, namely electricity and solid fuel uses. Both energy sources are expected to have distinct health effects on the population. From the hypothesis, electricity is expected to improve health and reduce mortality. In contrast, solid fuel use is linked with indoor air pollution which exposes the population to greater health burden. The link between income and health is still a source of heated debate. For example, Wilkinson (1992) pointed out that income is a key determinant of health. In contrast, Marmot (2004) suggests income is not important for health. Mellor and Milyo (2002) found no evidence on the association between income and health and claimed that the previously reported results are statistical artifacts. Thus, it is worthwhile to reassess the effects of income on health.

The empirical strategy is framed based on the permanent- transitory specification of equation which reveals some dynamics of the electricity use – health relationship, without having to specify a lag structure (that is lag effects of electricity and solid fuel use on health). The strategy follows the transformation is proposed by van Praag et al. (2003), which allows an explicit decomposition of the effect of electricity use into two distinct effects. Differences in the average electricity use, approximate the permanent effect and the deviations from the mean electricity use, approximate transitory effects. Egger and Pfaffermayr (2003), show that this specification can be viewed as an approximation of a general dynamic autoregressive distributed lag model. Thus, they show that it provides an approximation of the transitory and permanent effects of the decomposed variables (electricity and solid fuel use) when an inference in a dynamic model is not feasible. They report that it is a representation of a model with lagged exogenous variables where the unspecified lag dynamics are fully compensated by the inclusion of the group means. The focus of analysis is not on the dynamics per se, but on highlighting that there are different transitory and permanent effects of changes in electricity use and solid fuel on health indicators. It reveals the dynamics of the effects of electricity and solid fuel use on health indicators. The approach is similar to Friedman (1957) in the study income and consumption. So, in using the empirical strategy by van Praag et al. (2003), the relative importance of electricity and solid fuel uses on health indicators regarding both a transitory and a permanent effect, can be assessed in one equation.

It will be further useful to explain the economic intuition of the decomposition of the permanent - transitory impact of electricity and solid fuel use on health. Holding other regressors constant, one might expect that the impact of an increase in the electricity use might be cumulative. It can be expected the same when it comes to the effects of a change in the electricity use on health. These effects might be felt for many years after the event of the rise of the energy use. For example, it may take time for the health to improve. Therefore, transitory changes in electricity use may not have as much of an effect on health as a more permanent change in the electricity use. The effect of an increase on electricity use on health may take a long time to manifest itself on health, and, thus, one should not expect the only effect of electricity use on health to be of the contemporaneous nature. Also, deprivation of electricity use effects on health, should not be expected to be contemporaneous, but that this deprivation of electricity use plays out its impact on health over the long term.

4. Methodology and data

4.1. Methodology

4.1.1. Motivations

As discussed earlier, this study investigates whether the permanent and transitory effect of electricity and solid fuel use can explain health in Africa. The empirical strategy is based on van Praag et al. (2003), and four advanced econometric methodology. First, it uses the standard fixed effects regression methodology, which controls for the unobserved in the dataset. Second, it uses the Mundlak methodology to dissect the permanent and transitory components of electricity and solid fuel on health. This study considered the Mundlak methodology for several reason. (a) unlike the FE, the Mundlak method helps to break down the energy effect on health into permanent and transitory effects. For example, the fixed effect (FE) model omitted necessary information in the long run, which is essential for policy purposes (Baltagi et al., 2018; Hsiao and Zhou, 2018). (b) the FE model says nothing about the causality of independent variables that do not change over time (Nerlove, 2005), making the Mundlak more attractive to the present research. Therefore, it is reasonable to use Mundlak decomposition to uncover the permanent and transitory effects of electricity and solid fuel use on health, which can provide new knowledge for policymakers to tackle energy deprivation in Africa. Third, the study control for potential endogeneity in the dataset by using the Hausman-Taylor (1981) methodology. Fourth, the analysis is further strengthened by correcting for cross panel correlation using FGLS estimator.

4.1.2. Basic econometric framework

Since the research investigates the permanent - transitory effects of electricity and solid fuel use on health using a panel econometric framework, the Eq. (1) is re-specified as Eq. (2), as follows.

$$H_{j,t} = X_{j,t}\beta + \phi E_{j,t} + \eta\, I_{j,t} + s_j + \varepsilon_{j,t} \tag{2}$$

where for country j and year t, H denotes health measures in each country, X denotes a vector of other covariates or relevant factors. A time trend, E *is* energy demand in each country and is decomposition and proxy with (*Elect*$_{i,\ t}$) refer to electricity consumption and *solid fuel* (*solid*$_{i,\ t}$) use, and I is per capita income in each country. For the two last terms s *and* ε, are an unobserved factor of the error term, and the former is country specific. It is also assumed s *and* ε are normally distributed, and the variance can be measured as:

$$s_j \sim N\left(0, \sigma^2\right)$$

$$\varepsilon_{j,t} \sim N\left(0, \sigma^2\right)$$

4.1.3. Extended model: decomposing the transitory - permanent of electricity and solid fuel use on health

Intuitively, the fixed effects model has the ability to control for state-specific effects, but it suffers from two potential pitfalls. First, it suggests that the state effect is constant over time, a presumption that is unlikely to be sufficient due to socio-economic circumstances affecting changes in energy policies. Second, the effects of invariant factors are treated as a single fixed effect, making it impossible to disentangle the permanent and transitory effects of the variable for policy purposes (Rendon, 2013; Ning and Liu, 2017; Breitung and Salish, 2020) To circumvent these problems, another strategy would be to use the random effects estimator, where s_j is taking and model as a random factor. It also has its own shortcomings because it assumed:

$$E(s_j|X_j, E_j, I_j) = 0 \tag{3}$$

This assumption is unlikely to hold.

To resolve the conflict, Mundlak (1978), suggested a compromise to between the fixed and random effects, which is often cited by Greene (2008), coined out from Eq. (5) and specified as:

$$E(s_j|X_j, E_j, I_j) = X_,\beta + \overline{E_j}\phi^m \tag{4}$$

where the bar on a vector of factor represents the average or mean value of variables for each country or state. Using the random effect form of Eq. (4), the Mundlak specification becomes:

$$H_{j,t} = X_{j,t}\beta + \phi E_{j,t} + \eta\, I_{j,t} + X_,\beta + \overline{E_j}, \phi^m + \varepsilon_{j,t} + \left(s_j - E\left(s_j|X_j, E_j, I_j\right)\right)$$

or

$$H_{j,t} = X_{j,t}\beta + \phi E_{j,t} + \eta\, I_{j,t} + X_,\beta + \overline{E_j}, \phi^m + \varepsilon_{j,t} + \mu_j \tag{5}$$

$$\mu_j = \left(s_j - E\left(s_j|X_j, E_j, I_j\right)\right),$$

Interestingly, the Mundlak specification in Eq. (5) maintains the random effect specification that helps to address the problem of any correlation between the unobserved effect (*spcifically*, s_j) (see Greene, 2008), and the regressor (Baltagi, 2005, 2006; Greene, 2008; Campello et al., 2019). Without using lag structure, Eq. (5) uncovered some dynamic on the link between energy and health. It unveiled the permanent and transitory effect among the factors.

van Praag et al. (2003) and Steel (2020) developed and propose a transformation approach to reveal the dynamic from the factors specified in Eq. (5). Hence, the term $\phi E_{j,t} + \overline{E_j}\,\phi^m$ can be transformed as $\left[\left(E_{j,t} + \overline{E_j}\right)\phi + \underset{-}{E_j}(\phi + \phi^m)\right]$. This allows the effects of energy to be clearly broken down into two. Where, the energy deviation from average is capture with $\left(E_{j,t} + \overline{E_j}\right)$, the estimated coefficient of transitory effect or temporary is represented as ϕ,and the coefficient of the permanent or average state is represented as $(\phi + \overline{\phi})$. It is obvious that the permanent and transitory effect energy and health can be evaluated simultaneously with this Mundlak framework.

The main problem frequently cited is that the key variables can be correlated with the random effect of the state level that results in the endogeneity bias (Hausman and Taylor, 1981; Arellano and Bonhomme, 2012; Wooldridge, 2019). To address this shortcoming, the fourth approach proposed by Hausman and Taylor (1981) for correction of endogeneity found within the framework of Mundlak specification, is applied. Additionally, it uses FGLS to account for cross-panel correlation.

Briefly, the estimation is implemented as follows. First, the analytical framework starts by reviewing and clarifying the distinctions between the two approaches (FE and RE) and their purpose in panel econometric analysis. Second, it presents the proposed Mundlak approach with the formal treatment of permanent and transitory effects. To address the potential endogeneity issue, the Mundlak methodology was extended using the Hausman-Taylor (H-T) method. Furthermore, it uses the FGLS estimator to correct for cross-panel correlation.

4.2. Data

This study explores the permanent and transitory health effects of electricity and solid fuel uses for a panel of 29 Sub Saharan African countries for the period of 1990 to 2015. The annual data are sought from the International Energy Agency (IEA), World Development Indicator (WDI), World Health Organisation (WHO). The countries consider having similar growth trajectories. The dependent variable is overall health, which is a proxy for overall mortality (crude death rate, per 1000 population), and data were obtained from the WHO database. The independent variable is type of energy use, consisting of electricity usage (kWh per capita) and solid fuel use (per capita for cooking and heating), and data from IEA and WDI. Other control variables include the percentage of the population with access to an improved water source and data from WDI. Indoor air pollution is measured by PM $_{2.5}$ indoor air pollution, mean annual exposure (microgram per cubic meter), and data are available at the WDI. Regarding data on education, the primary school enrolment (%), obtained from the WDI. Data on Gross Domestic Product per capita (constant 2010 US$) were obtained from the WDI. The data and descriptions are provided in Table A and list of African countries in Table B (see Appendix).

5. Empirical results

This section reports the empirical result and discusses the findings in two folds. First, it presents the main results by analysing the permanent and transitory effects of electricity consumption and solid fuel use on the overall health of the population. Second, it discusses the findings and the contributions of the study to existing literature.

5.1. Summary statistics

The analysis begins with the summary statistics, which reflects the prior behaviour of the variables including the mean and standard deviations. Table 1 provides evidence on the summary statistics. The first column for overall and the second column is the state level and years.

The highest mortality is about 38.2 per 1000 people and lowest about 16.2 per 1000 people. The maximum electricity use per capita is about 9986 kwh and minimum are about 0.15 kWh. For solid fuel use, the maximum is about 2.49 per capita and lowest is 0.06 per capita. For the state level sample, the maximum electricity use per capita is about 984 kWh and lowest is 20.1 kWh, while the maximum and minimum of solid

Table 1
Summary statistics.

Variables	Overall mean		State average		
	Below/ min	Above/max	Below/ min	Above/ max	
Overall mortality rate	16.2	38.2.39	9.8	32.1	501
Electricity use	0.15	9986	20.1	984	751
Solid fuel use	0.06	2.49	0.15	0.98	562
Indoor pollution	1.1	46.6	3.32	21.0	456
Access to water	0.19	95.0	1.23	56.1	613
Education	25.1	82.6	1.23	78.4	439
Income per capita	504.2	12,064.78	249.95	19,854.9	780
Health expenditure	14.75	23,935.45	1.23	56.1	613

Notes: *Overall Mortality rate, (crude per 1000 people) (overall mortality), electric power consumption (kWh per capita) (electricity); per capita solid fuel consumption, (solid fuel); access to water (water access), Current health expenditure per capita (current US$), (health exp); School enrolment, primary (% gross); PM $_{2.5}$ air pollution, mean annual exposure (micrograms per cubic meter) (indoor air pollution); gdp per capita (constant US$).*

fuel per capital is about 0.98 and 0.14, respectively.

5.2. *Baseline estimates*

Generally, the starting point of panel data analysis is to estimate the fixed effect model, which assumes that the unobserved state-specific component of the error term has fixed effect relations with the dependent variable (Hoderlein et al., 2010; Li et al., 2016; Hsiao and Zhou, 2018). Table 2 presents the results of standard fixed effects panel regression on the effects of electricity and solid fuel use on overall mortality.

The empirical results from Table 2, Column (1) present the estimated coefficient of the basic model of Eq. (1). The results indicate that electricity has a negative and statistically significant relationship with overall mortality, whereas solid fuel use has a positive but insignificant relationship with overall mortality. The empirical results supported the main hypothesis and were consistent with prior research by Acheampong et al. (2021a, b) and Banerjee et al. (2021). Acheampong et al. (2021a, b) and Banerjee et al. (2021) has shown that there is a close relationship between electricity use. Their finding also suggests that countries with higher electricity deprivation problem are more likely to experience higher mortality. Obviously, the insignificant of solid fuel use on overall mortality suggests that if electricity is readily available, there may be concern about indoor air pollution (see Gohlke et al., 2011). The findings imply that solid fuel combustion may be unhealthy when electricity is readily available.

Each of the subsequent columns (2–6) in Table 2 presents the augmented version of the basic model using fixed effect panel regression estimation testing for other determinants of overall mortality. According to the results, indoor air pollution has a positive and significant effect on overall mortality, while health expenditure has a negative and significant relationship with overall mortality. In addition, income and education are negative but has an insignificant impact on overall mortality.

Two points can be inferred from the analysis. First, theory suggest that increase in solid fuel use is associated with increase mortality, which is confirmed by the analysis. The result imply that solid fuel usage has long term health effects on the population. Second, the results also confirmed that readily and availability of electricity for use can help reduce the health risk.

5.3. *Mundlak methodology*

As earlier discussed, the standard panel fixed effect regression is suitable for controlling unobserved, but it has some important and well-known limitations (Breitung and Salish, 2020; Wooldridge, 2019). Firstly, it assumes that the state effect does not change. This is a strong assumption that is unlikely to hold, because of the changes in macroeconomics. For example, possible changes in energy and health policies make it unlikely for the state effect to be fixed over time. Secondly, the effects of time invariant elements combine to create a single fixed effect, thus making it difficult to assess the permanent and transitory components. While the importance of permanent and transitory is poorly neglected or ignored, its evidence is crucial for formulating the energy policy needed in promoting the health of the population. If the impact of electricity on health is not contemporaneous, then the effects of changes in energy use (electricity and solid fuel) may take a long time to manifest. To capture this distinction, the transitory-permanent impact is decomposed and estimated using the Mundlak (1978) methodology. Table 3 presents the results of the Mundlak specification on the effects of permanent and transitory effects of electricity and solid fuel use on overall mortality.

In Table 3 the results indicates that the coefficient of the transitory effect of electricity use has a negative relationship with overall mortality

Table 2

Fixed effects panel estimations of the effect electricity and solid use on use overall mortality.

Dependent variable: overall mortality						
Independent variables	(1)	(2)	(3)	(4)	(5)	(6)
Electricity	−0.0053*** (0.001) [−5.28]	−0.0047*** (0.001) [−4.50]	−0.0047*** (0.001) [−4.50]	−0.0047*** (0.001) [−4.42]	−0.0043*** (0.001) [−3.65]	−0.0040*** (0.001) [−3.61]
Solid	12.54 (8.92) [1.41]	11.38 (8.7) [1.30]	11.73 (8.9) [1.31]	12.21 (9.3) [1.31]	12.9 (9.3) [1.31]	21.73** (9.61) [2.25]
Indoor air pollution		4.77*** (0.76) [6.22]	4.77*** (0.76) [6.22]	4.80*** (0.77) [6.13]	4.76*** (0.77) [6.06]	4.77*** (0.76) [6.22]
Water access			0.001** (0.00) [1.79]	0.001** (0.00) [1.79]	0.001** (0.00) [1.79]	0.001** (0.00) [2.52]
Education				−0.37** (1.4) [−0.26]	−0.49 (1.43) [−0.35]	0.35 (1.45) [0.24]
Income					0.002 (0.00) [−1.36]	−0.002 (0.001) [−1.59]
Health exp						−0.006*** (0.001) [−3.35]
Constant	163.8 *** (9.64) [16.9]	103.55*** (13.30) [7.77]	103.5 (13.3) [7.77]	103.2 (13.3) [7.71]	106.5 (13.6) [7.83]	122.1*** (14.31) [8.54]
Country dummy	yes	yes	yes	yes	yes	yes
Obs. countries	29	29	29	29	29	29
Wald ch2	1619.7***	1747***	1747**	1745	1748	1784***
p-value	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]

Notes: *Overall mortality rate, (crude per 1000 people) (overall mortality), electric power consumption (kWh per capita) (electricity); per capita solid fuel consumption, solid fuel); access to water (water access), Current health expenditure per capita (current US$), (health exp); School enrolment, primary (% gross); PM* $_{2.5}$ *air pollution, mean annual exposure (micrograms per cubic meter) (indoor air pollution); gdp per capita (constant US$). [] is t-statistic, * * * , * * , * denotes statistical significance at* 1 % , 5 % *and* 10% *levels, respectively.*

Table 3
Mundlak estimations on transitory and permanent effects of electricity and solid fuel use on overall mortality.

Variables	Overall mortality			
	Transitory		Permanent	
	(1)	(2)	(3)	(4)
Electricity	−0.0053***	−0.0051***	−1.41***	−1.23***
	(0.00)	(0.001)	(0.14)	(0.001)
	[−5.37]	[−3.77]	[−10.8]	[−8.34]
Solid	12.0	20.65**	46.45**	63.8**
	(8.87)	(9.48)	(18.66)	(19.85)
	[1.35]	[2.18]	[2.46]	[3.22]
Indoor air pollution		4.18***		4.02***
		(0.75)		(0.75)
		[5.53]		[5.54]
Water access		0.001**		0.001**
		(0.00)		(0.00)
		[2.05]		[1.69]
Education		1.08		−0.79
		(1.34)		(1.25)
		[0.83]		[−0.63]
Income		−0.002		−0.002**
		(0.001)		(0.001)
		[−1.27]		[−1.82]
Health exp		−0.005***		−0.003***
		(0.001)		(0.00)
		[−3.76]		[−2.28]
Constant		104***	154.5***	118.6***
		(16.3)	(14.99)	(17.5)
		[6.38]	[10.31]	[6.77]
Obs. countries	29	29	29	29
Wald ch2	29.8***	82.73***	111.2***	160.4***
p-value	[0.00]	[0.00]	[0.00]	[0.00]

Notes: *Overall mortality rate, (crude per 1000 people) (overall mortality), electric power consumption (kWh per capita) (electricity); per capita solid fuel consumption, solid fuel); access to water (water access), Current health expenditure per capita (current US$), (health exp); School enrolment, primary (% gross);* $PM_{2.5}$ *air pollution, mean annual exposure (micrograms per cubic meter) (indoor air pollution); gdp per capita (constant US$). [] is t-statistic, * * * , * * , * denotes statistical significance at* 1 % , 5 % *and* 10%*levels, respectively.*

and is statistically significant. The results are somewhat similar to that of the standard fixed effects regression. For the permanent effects, the coefficients of electricity use (e.g., difference in average electricity use) exert a greater and negative effect on overall mortality. There is a noticeable different in the size and coefficient of the transitory and permanent effects of electricity use on overall mortality, with the change in permanent effect having a greater impact on overall mortality than a transitory change in electricity use. On the contrary, the transitory effect of solid fuel use on overall mortality remains positive and statistically insignificant. Interestingly, the permanent effect of solid fuel on overall mortality is positive and statistically significant. The relative size of the coefficient is much different, with a change in permanent effect having a greater impact on overall mortality than a transitory change in solid fuel use.

The results confirm the earlier hypothesis that the increase is electricity can be cumulative and the effect of a change in electricity use on health can be felt only after many years of energy use. Therefore, effect of electricity use on health is not contemporaneous. Similarly, the effect of solid fuel on health can only manifest after many years of consistent use. It expected that after many years of solid fuels use the associated indoor air pollution will manifest on health of the population.

5.4. Correcting for endogeneity

While the Mundlak methodology offers a compromise between the standard fixed effect (FE) and random effect RE estimators (Bender and Theodossiou, 2015), it overlooks a potential endogeneity issue. The presence of potential endogeneity may cause imprecise inference on the relationship between energy and health. In Eq. (1), endogeneity may arise from two sources. First, research suggests that the direction of causality runs from energy to health, in the sense that lower electricity use can lead to worse health conditions, but causation may run in the opposite direction. While energy deprivation can worsen health, unhealthy people may also not be efficient at contributing to generating electricity. Second, it is likely that some of the independent variables are correlated with state-level random effects (Hausman and Taylor, 1981). In the first case, potential endogeneity originating from reverse causality is unlikely. However, the second possible source may be substantial. A common solution is to use an instrumental variable (IV) to address these potential shortcomings. However, this is difficult to achieve because the use of IVs requires a valid instrument that must meet some specific conditions. The instrument must be uncorrelated with the error term but correlated with endogenous explanatory variables (Murray, 2006; Bender and Theodossiou, 2016), and it must satisfy both endogenous and exogenous conditions. While identifying a strong, relevant, and potential IV is difficult, having a weak instrument may undermine the performance of an econometric model (Bettis et al., 2014).

While the traditional IV method may appear promising for identifying the structural effects of interest, the application is not without imprecise inference. One suggested approach to improve the accuracy of the IV method is using many instruments (see Amemiya, 1966; Chamberlain, 1986; Newey, 1990). Unfortunately, the expected increase in efficiency may appear motivating, but the use of many instruments can undermine the inference (Bekker, 1994; Hansen et al., 2008; Chao et al., 2012). Thus, the problem of using many IVs can be discussed in two scenarios. First, imprecise inference can be reported when weak instruments are used (Staiger et al., 1997). Second, imprecise inference can be reported when many weak instruments are used (Chao et al., 2012). Apparently, the IVs procedures support the traditional method for identifying the structural effects but are unlikely to be the universal solution to many instruments problem.

To tackle endogeneity, Hausman and Taylor (1981) suggested using internal and country dummy variables together as instruments. Obviously, the use of IV based on Hausman – Taylor methodology used in applied research for ensuring improved efficiency and precise inference. It involves inclusion of the dummy variables adjusts for omitted variable bias driven by macroeconomic policy, infrastructure deficits, political tension, and other factors. Table 4 reports the results of the Hausman–Taylor specification (Hausman and Taylor, 1981).

After correcting for endogeneity, the results showed a negative and slight increase in the statistically significant level of the coefficient for the permanent and transitory effects of electricity use on overall mortality. However, the transitory effects remain negative and statistically significant and seem to be similar to those of the FE regression. Interestingly, the relative size of the coefficient differs; a permanent change has a larger marginal effect on overall mortality than a transitory change in electricity use. On the contrary, the coefficient of solid fuel use exerts greater permanent effects on overall mortality, but the transitory effect of solid fuel use is still missing.

5.5. Controlling for cross-panel correlation

The Hausman–Taylor specification has been used to correct for endogeneity, this approach is unlikely to be sufficient for correcting the potential cross-panel correlation in the right-hand side of Eq. (1). This implies that Eq. (1) is only estimated efficiently when $COV\ (\varepsilon_{jt}, \varepsilon_{is}) = 0$; $for\ j \neq i\ and\ t \neq s$. If this condition is violated, then the estimated coefficient and standard error are unlikely to be correct. For example, variables $X_{j,\ t}$, $E_{j,\ t}$, and $I_{j,\ t}$ are highly likely to correlate with $\varepsilon_{j,\ t}$.

Another approach to correcting for cross-panel correlation is using the feasible FGLS estimator. When there is a correlation, the FGLS estimator allows for covariance between the variables and offers more reliable estimates than other estimators. However, the FGLS estimator has some shortcomings. There may be a reduced efficiency when the

Table 4
Hausman-Taylor estimations on transitory and permanent effects of electricity and solid fuel use on overall mortality.

Variables	Overall mortality			
	Transitory		Permanent	
	(1)	(2)	(3)	(4)
Electricity	−0.0056***	−0.004***	−1.37***	−1.27***
	(0.00)	(0.001)	(0.14)	(0.001)
	[−4.16]	[−3.61]	[−9.30]	[−8.66]
Solid	13.1	21.73**	51.09**	60.24**
	(8.9)	(9.6)	(19.21)	(20.3)
	[1.48]	[2.25]	[2.66]	[2.96]
Indoor air pollution		4.53***		4.26***
		(0.77)		(0.73)
		[5.84]		[5.79]
Water access		0.001**		0.001**
		(0.00)		(0.00)
		[2.52]		[1.62]
Education		0.35		−0.79
		(1.45)		(1.25)
		[0.24]		[−0.63]
Income		−0.002		−0.002**
		(0.001)		(0.001)
		[−1.59]		[−1.82]
Health exp		−0.006***		−0.005***
		(0.001)		(0.001)
		[−3.33]		[−2.28]
Constant	129.9***	159.6***	187.2***	206
	(13.1)	(35.14)	(24.84)	(36.3)
	[9.9]	[4.5]	[7.54]	[5.69]
Country dummy	Yes	yes	yes	yes
Obs. countries	29	29	29	29
Wald ch2	1628.3***	1784.2***	1885***	2029.9***
p-value	[0.00]	[0.00]	[0.00]	[0.00]

Notes: *The endogeneity correction procedure control for instrumental variables specification to control between energy variables and random effect term. Regression includes covariates listed in 2. Numbers in parentheses are the coefficient standard error () and t-statistics []. The signs* * * * , * * , * *denotes statistical significance at* 1 % , 5 % *and* 10%*levels, respectively.*

Table 5
Feasible GLS estimations on transitory and permanent effects of electricity and solid fuel use on overall mortality.

Variables	Overall mortality			
	Transitory		Permanent	
	(1)	(2)	(3)	(4)
Electricity	−0.006***	−0.008***	−1.1***	−1.6***
	(0.00)	(0.00)	(0.00)	(0.00)
	[−374.05]	[−251.6]	[−589.7]	[−8.66]
Solid	8.6***	12.7***	52.89**	69.24***
	(0.08)	(0.18)	(0.00)	(0.35)
	[106.86]	[67.7]	[248.08]	[196]
Indoor air pollution		0.89***		0.067***
		(0.00)		(0.01)
		[60.8]		[52.47]
Water access		−0.002**		−0.001***
		(0.00)		(0.00)
		[−23.6]		[−261.0]
Education		3.82***		2.65***
		(0.00)		(0.01)
		[0.24]		[200.1]
Income		0.002***		−0.002***
		(0.00)		(0.00)
		[−58.30]		[−22.02]
Health exp		−0.006***		−0.003***
		(0.001)		(0.00)
		[−227.5]		[−191.0]
Constant	144.5***	148.6***	143***	140.09***
	(0.00)	(0.23)	(0.00)	(0.19)
	[1548]	[638.0]	[1643]	[719.0]
Obs. countries	29	29	29	29
Wald ch2	147693***	311930***	381929***	443,962.1***
p-value	[0.00]	[0.00]	[0.00]	[0.00]

Notes: *All regression includes covariates listed in Table 2. All dependent variables are in natural log form. Number in parentheses are standard error () and t-statistics []. The signs* * * * , * * , * *denotes statistical significance at* 1 % , 5 % *and* 10%*levels, respectively.*

number of periods is less than the number of panels. However, given that reduced efficiency is unlikely to change the coefficient of the variables, research suggests that using the FGLS estimator is better than assuming no correlation. Table 5 reports the coefficients of the transitory and permanent effects of electricity and solid fuel use on health.

After correcting for cross-panel correlation, the coefficients are more statistically significant and efficient. The coefficient of transitory and permanent effects of electricity uses on overall mortality remain negative and statistically significant. While the result of the transitory impact looked like that of the standard panel fixed effect regression in signs and magnitude, the coefficient is still less than that of permanent impact. Interestingly, the transitory effect of solid fuel use on overall mortality became is positive and statistically significant after correcting for cross panel correlation. Also, a positive permanent effect of solid fuel use on overall mortality is observed. It is also imperative to note that the relative size of the coefficient differs, with a change in permanent impact having a larger marginal effect on overall mortality than a transitory change in solid fuel use.

5.6. Discussion of findings

In this paper, we examined, formalised, and tested three prominent hypotheses on the permanent and transitory effects of electricity and solid fuel use on health (proxy with mortality). The empirical strategy was based on van Praag et al. (2003), which helped to construct and decomposed the permanent and transitory effects into a single equation. The research methodology was framed in Mundlak methodology. The analysis began with the panel fixed effect regressions which assumed that the unobserved state component of the error term has a fixed relationship with the dependent variable. It then proceeded to acknowledge the lagged components without having to specify lagged structure using the Mundlak (1978) approach to explicitly consider the permanent and transitory impact of electricity and solid fuel use on health. The analysis further elaborated on the control for potential endogeneity issues using the Hausman and Taylor (1981) statistical procedure. Further analysis and robustness checks were implemented to control for cross panel correlation using the Feasible GLS estimator. The results of the panel fixed effect regression confirmed that an increase in electricity use reduces overall mortality, whereas an increase in solid fuel use is associated with an increase in mortality. The evidence offered support for the hypothesis that electricity remains an important factor in health, and it is consistent with prior studies (see Acheampong et al., 2021a, b; Banerjee et al., 2021). The results of the Mundlak decomposition also confirmed that the coefficient of electricity use exerts a negative permanent and transitory effect on overall mortality. However, the estimated coefficient of the transitory effect of electricity is fewer compared to the permanent effect. On the contrary, On the contrary, the coefficient of solid fuel use exerts greater permanent effects on overall mortality, but the transitory effect of solid fuel use is still missing. The results of the Hausman and Taylor (1981) specification was similar to that of the Mundlak specification. Interestingly, the correction for endogeneity yielded a slight improvement in the coefficient. In fact, they were statistically significant for both permanent and transitory effects of electricity use on overall mortality, whereas no changes in signs were observed. Further analysis using the feasible GLS methodology indicated that the presence of the availability of electricity reduced the adverse effect of solid fuel on overall mortality. Also, solid fuel use exerts a positive and statistically significant transitory and permanent effect on mortality. These results were not only important for establishing the implication of the permanent and transitory effect of electricity and solid fuel on health, but they showed the important consequences of delay in policy intervention on the energy and health on the population in Africa.

5.7. Research contributions

This study makes several contributions to the literature in the theoretical, empirical, methodological, and societal areas.

5.7.1. Theoretical contributions

The study fits into the theoretical literature by applying the permanent income hypothesis (Friedman, 1957). While several studies have attempted to apply and test this hypothesis in different consumption-related problems, research focusing on the energy–health nexus is missing. Therefore, the current study fills this lacuna by testing the permanent and transitory effects of electricity and solid fuel use on health in Africa. Interestingly, the obtained results provide new information that will serve as a point of reference for studying the relationship between energy and health.

5.7.2. Empirical contributions

This study contributes to the fast-growing literature seeking to use advanced panel econometric analysis to explain the causality between energy use and health. It makes a substantial empirical contribution by testing the permanent and transitory effects of electricity and solid fuel use on health, which have been poorly neglected in previous research. A better understanding of the permanent and transitory component could help policymakers prepare urgent electricity needs of the people and provide more insight into the permanent consequences of electricity deprivation on health.

5.7.3. Methodological contributions

While most previous studies have used time series analysis, relatively few have used the FE and generalised method of moment (GMM) approach. Although the immediate challenge with time series is detecting an appropriate lag structure and over-parameterisation, the controversy surrounding the uses of FE and RE and GMM are still fundamental issues in empirical research. To overcome these challenges, three methodological contributions were made. First, we explored advanced econometrics based on the Mundlak methodology. Second, we corrected the potential endogeneity using the Hausman–Taylor specification. Third, we corrected the cross-panel correlation using the FGLS estimator. All of these contributions provided new information about the social implications of energy use on health and its associated mechanism.

5.7.4. Societal contributions

This study addressed the major socioeconomic problems related to the impacts of energy deprivation on health. Using a rigorous statistical methodology, it reflects a real situation and estimates the potential consequences of the permanent and transitory effects of electricity and solid fuel use on health. Furthermore, it provides information on hidden questions related to the associated areas that explain the connection between energy use and health in several ways. First, this study provides awareness of the implications of the permanent and transitory effects of two types of energy use on health. Second, it offers information that can promote behavioural adjustments and improve societal attitudes towards healthy living through a more efficient energy use that recognises the health risks associated with solid fuel. Third, it provides practical, social, and hands-on information for policymakers to formulate strategies to provide reliable and affordable electricity.

6. Conclusions

This study offers a broad perspective on the permanent and transitory effects of electricity and solid fuel use on health; its findings support the use of comprehensive policies to resolve the problem of energy deprivation in Africa. The empirical strategy followed the transformation proposed by van Praag et al. (2003), which helped explicitly divide the impacts into permanent and transitory components. We employed four econometric methodologies: the standard panel FE, the Mundlak (1978) methodology, the Hausman–Taylor (1981) specification, and the FGLS estimator.

The empirical result for the standard FE estimator indicated that electricity use exerted negative and statistically significant effects on overall mortality. In contrast, the result for solid fuel use was positive but had no significant effect on overall mortality. For the overall Mundlak specification, the transitory effects of electricity use were similar to those of the standard fixed effect regression; they remained negative and statistically significant. However, the permanent effects of electricity use had a negative impact and a greater coefficient than the transitory effects. For solid fuel use, the coefficient of the permanent effects was positive and statistically significant; it was also greater than the transitory effects coefficient.

The results of the Hausman–Taylor (1981) correction for endogeneity indicated a slight increase in the significance of the coefficients. However, the coefficient of the transitory effects was still smaller than that of the permanent effects for both electricity and solid fuel use. The coefficient of electricity use remained negative, and using solid fuel still exerted a positive and statistically significant effect on overall mortality. After correcting for potential cross-panel correlation implementing the FGLS estimator, the coefficient of electricity use exerted a negative and statistically significant effect on overall mortality, whereas that of solid fuel did not. Therefore, when electricity is widely available, the use of solid fuel may have no impact on overall mortality.

The empirical findings reaffirmed the relevance of providing readily available electricity to avert the use of toxic substances associated with solid fuel use. In particular, the results resonate with those of Banerjee et al. (2021), who highlighted the importance of electricity development for the health quality of populations in developing countries. The results are also comparable with those of Acheampong et al. (2021a, b), who showed that access to electricity is a key factor for improving health in energy-poor regions. Our findings confirmed the implications of the permanent and transitory effects of solid fuel use on overall mortality.

There are several policy implications associated with our findings. First, it showed that the standard FE estimator is not correct and does not provide an explanation of the impacts of electricity and solid fuel consumption on health. Indeed, the empirical results have shown that the effects of electricity on health and the use of electricity cannot be taken as contemporaneous, as it takes a long time for the impacts to be seen. By respecifying the model based on the Mundlak methodology, new information on the permanent effects of electricity was uncovered that can help policymakers resolve the electricity–health problem in the region. Second, the findings showed that the cumulative impact of electricity deprivation is harmful to population health. This is evidenced by the results of the permanent effects of solid fuel use on health. Policymakers must recognise that a short-term approach will not be sufficient to address the health consequences of electricity deprivation, and long-term electricity planning is necessary to attempt to reduce mortality in the region. Third, the coefficient was more statistically significant when using the Hausman–Taylor statistical method to correct for endogeneity. Fourth, the analysis was further strengthened by correcting for cross-panel correlation using the FGLS estimator.

The findings of this study may be useful to researchers and policymakers seeking to understand the permanent and transitory effects of electricity and solid fuel use on health in Africa. This study suggests the following:

- Sustainable investments in energy infrastructure can improve access to electricity and population health and reduce mortality.
- The improved provision of electricity can reduce exposure to indoor air pollution, which has been associated with solid fuel use.

- Expanding the use of clean fuels and technology is crucial to reducing indoor air pollution from solid fuels and safeguarding the public health in Africa. These include renewable energy sources like solar and electricity as well as biogas, liquefied petroleum gas (LPG), natural gas, alcohol fuels, and biomass stoves that adhere to the WHO Guidelines' emission targets.
- There are substantial permanent health benefits of electricity use for the overall population; policymakers should strive to ensure its availability for the teeming population of Africa.
- The African continents require a cooperative set of decision-supporting tools, principles, and resources to integrate energy policy into their future public health initiatives.

The finding of this research will be useful for researchers and policymakers seeking to explanation the permanent and transitory effects of electricity and solid fuel usage on health in Africa. For future studies, efforts to investigate the gender effects of electricity deprivation on health in Africa could add more information to the findings of the present study.

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CRediT authorship contribution statement

OA Shobande conceptualised, designed, analysis and interpretation of data and approved the final version for publication.

Declaration of competing interest

The author declares no potential conflicts of interest with respect to the research, authorship, and publication of this article.

Data availability

Data will be made available on request.

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Appendix A

Table A
Data definitions and sources.

Variables	Descriptions	Sources
Dependent variable		
Overall mortality	Mortality rate (crude death rate, per 1000 population)	World Bank
Independent variables		
Electricity use	Electric power consumption (kWh per capita)	IEA
Solid fuel use	Per capita solid fuel consumption for cooking and heating.	WHO
Other controls		
Indoor air pollution	PM $_{2.5}$ air pollution, mean annual exposure (micrograms per cubic meter) (indoor pollution)	World Bank
Access to water	Improved water source (% of population with access)	World Bank
Education	School enrolment, primary (% gross)	World Bank
Income per capita	GDP per capita (constant 2010 US$).	World Bank
Health expenditure	Health expenditure per capita (current US$)	World Bank

Table B
List of African countries.

Selected African countries									
1	Angola	7	Cape Verde	13	Equatorial Guinea	19	Uganda	25	Nigeria
2	Benin	8	Central Africa Republic	14	Gabon	20	Eritrea	26	South Africa
3	Burkina Faso	9	Chad	15	Gambia	21	Madagascar	27	Niger
4	Burundi	10	Congo DRC	16	Ghana	22	Malawi	28	Zambia
5	Togo	11	Cote d' ivories	17	Mauritius	23	Mali	29	Zimbabwe
6	Cameroon	12	Comoros	18	Kenya	24	Ethiopia		

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