Energy Efficiency Capitalization

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June 11, 2024

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Abstract

Energy efficiency plays a pivotal role in attaining other sustainable development goals. This paper studies the impact of the National Energy Efficiency Strategy (NEES), the largest energy efficiency programme in South Africa, targeting low-income households. Using the traditional difference-in-differences estimator on South African generalized household survey data, the variations in NEES eligibility conditions are exploited to evidence a rebound effect that persists in the long-term. Moreover, there are significant capitalizations in the housing market, with sizable environmental and health improvements. This study argues that pollution reductions, especially in the air, water, littering, and asbestos exposure, are only conduits for non-chronic morbidity reductions in tuberculosis, diarrhea, respiratory infections, and depression. The heterogeneous characterizations of these effects are explored, discussing policy insights. Energy efficiency adoption among Blacks and Asians, and modern energy usage are more urbanized in both low- and densely (Gauteng, Kwazulu-Natal and Western Cape) populated provinces, causing rising house prices and rents in these locations. Albeit there are ubiquitous pollution reductions, it is more pronounced in the densely populated metropolitan provinces, causing public health gains for adults, youths, and children, across all genders, races, and locations in high-density provinces. Reassuringly, these results subsist across different robustness checks and falsification exercises.

Keywords: Energy Efficiency, Energy Usage, Housing Market, Pollution, Morbidity

1 Introduction

Energy efficiency offers unlimited opportunities for mutual benefit through the implementation of aggressive energy conservation policies (Fowlie et al. 2018; Allcott and Greenstone 2012). These benefits involve reductions in externalities (health problems and climate change) caused by energy inefficiency. In 2004, the residential sector accounted for 17.9% of final energy demand in South Africa. Much of this energy consumed is biomass-based. Thus, presenting opportunities for energy savings and pollution mitigation measures of international significance. Hence, the national government sought for policies to improve energy efficiency in the country via the national energy efficiency strategy (NEES). They set a

target for the residential sector of a 10% improvement in energy efficiency by 2015 (*The National Energy Efficiency Strategy* 2008). Consequently, efficiency improvements between 2000 and 2012 have resulted in a fall in household energy consumption by 28% significantly above the NEES target (*South Africa's Energy Efficiency Target - 2nd Annual Monitoring Report* 2015). [1]

Given this achievement, the government of South Africa embarked on a post-2015 NEES (*1st Draft: Post-2015 National Energy Efficiency Strategy* 2015). This aims to consolidate the previous achievements, stimulating further energy efficiency improvements through a combination of fiscal incentives, a robust legal and regulatory framework, and enabling measures. [2] It sets two targets to be achieved by 2030 relative to 2015 baseline: (i) a 33% reduction in the energy consumption of new household appliances; (ii) a 20% improvement in the energy performance of new buildings. A glance at panel A of Figure 1 shows that there is a steady increase in the proportion of NEES-compliant low-income households since 2011, suggesting that South Africa is on track to achieving their 2030 energy efficiency target for the residential sector.

This study makes four important contributions to the developing countries' literature. First, it is the first study to document evidence on the effect of energy efficiency on household energy use in developing countries. Indeed, in developed countries such as in North America and Europe, the literatures have documented significant decreases in household's average energy consumption due to energy efficiency improvements (Fowlie et al. 2018; Kotchen 2017; Adan and Fuerst 2016; Levinson 2016; Jacobsen and Kotchen 2013; Allcott and Greenstone 2012; Costa and Kahn 2011; Metcalf and Hassett 1999). However, Davis et al. (2014) evinced a heterogeneous effect of energy efficiency on energy consumption in Mexico. Conversely, this study finds a rebound effect of an energy efficiency programme in South Africa.

Second, it is the first study to use quasi-experimental designs to investigate the effect of energy efficiency on the house prices and rents for a developing country. NEES established a mandatory standard on the energy performance of new residential housings in South Africa (*South African National Standard: Energy Efficiency in Buildings* 2011). This raises the question, whether energy efficiency is capitalised in the

[1] It can be assumed that the target of a 10% improvement in energy efficiency implies a 10% reduction in the amount of energy required for a given level of activity. South Africa's Department of Energy measured efficient energy use in terms of socioeconomic group classfication of households' electricity use for lighting, cooking, water- and space-heating purposes.

[2] As at 2015, the residential sector accounts for 25% of the final energy demand, notable rebound effect of NEES. South Africa's Department of Energy (DoE) has the vision to promote energy efficiency as the first-fuel in driving balanced, socially inclusive and environmentally sustainable economic growth, boosting job creation and leading technological innovation across the Sub-Saharan African region. The first-fuel concept is gaining increased credence worldwide. Energy efficiency is considered to be a hidden energy resource that should be fully exploited before considering other sources as it takes less time to implement, lasts longer and keeps producing without the negative effects of generation.

housing market in South Africa? The closest literatures on house prices and rents are in Europe and North America (Ferentinos et al. 2023; Gaur and Lang 2023; Aydin et al. 2020; Qiu et al. 2017; Dröes and Koster 2016; Dastrup et al. 2012). Albeit these papers used quasi-experimental designs, their results are inconclusive due to different identification strategies in developed countries. There are also existing non-causal literatures on house prices focusing on Australia, European and North American countries, whose results are inconclusive (Williams et al. 2023; B. Zhang et al. 2023; Evangelista et al. 2022; Taruttis and Weber 2022; Dröes and Koster 2021). Moreover, whereas previous causal studies inconclusively focused on the capitalisation of energy efficiency on house prices in developed countries, this study provides causal evidence of its effect on house prices and rents for a developing country. Consistent with the literatures using energy efficiency adoption identification strategy (Aydin et al. 2020; Lan et al. 2020; Qiu et al. 2017; Eichholtz et al. 2010), I find significant capitalizations in the housing market in South Africa due to energy efficiency improvements.

Third, it examines the effect of energy efficiency on the environment—pollution outcomes. Given the importance of energy efficiency in reducing the externalities from climate change, this study provides causal evidence on the effect of energy efficiency improvements on the environment in terms of pollution (littering, air, water and noise) and land degradation. The literature on pollution reduction effect of energy efficiency is quite meagre and comes from engineering, lacking causal evidence. In addition, this literature exclusively focused on the environmental impact on one pollution outcome—air pollution (S. Zhang et al. 2015; 2014). This could be attributed to lack of available data. This study attempts to extend this literature by presenting the first causal evidence on the environmental impact of energy efficiency improvements, focusing on air, water and noise pollution, littering and land degradation in a developing country. The results are consistent with the pollution reductions argument of energy efficiency improvements. This evidence of pollution reductions will provide deeper explanations on the transmissions mechanisms of public health gains.

The fourth contribution examines the effect of energy efficiency on public health outcomes. Many literatures have argued for the public health benefits of abated air pollution and vice versa, in terms of morbidity and mortality rate reductions in both adults and children. These literatures are both non-causal (Kearns

et al. 2023; Rajaei et al. 2018; Singh et al. 2018; Hertz-Picciotto et al. 2007; Lin et al. 2007; Raizenne et al. 1998; Bates 1995; Lave and Seskin 1970; McDermott 1961) and causal (Sheldon and Sankaran 2017; Schlenker and Walker 2016; Greenstone and Hanna 2014; Currie and Neidell 2005; Chay and Greenstone 2003), however they neglect the effect of energy efficiency. They argued for a pathophysiological transmission mechanism on public health benefits of pollution reductions. This study presents a more global picture of public health gains ascribing it to energy efficiency improvements. It argues that, the pollution reductions effect of energy efficiency improvements serve as a conduit towards public health gains in non-chronic morbidity—respiratory infections, diarrhoea and severe tuberculosis (TBC) in South Africa. I further document evidence of mental health gains caused by energy efficiency upgrades.

The confidence in the recovered causal impacts rests on a number of robustness checks conducted including pre-trends testing, potential selection issues, internal validity checks, and alternative clustering of the standard errors, model specifications and quasi-experimental design. The outcome trends between the treated and never-treated households were compared before the treatment to conclude on the absence of any linear pre-trends in the outcomes. This implies that the evolution of the outcomes between the treated low-income households and the never-treated before the treatment were in parallel. Furthermore, a number of counterfactual exercises were conducted on the outcomes using animal dung as an energy source, price of informal dwellings, urban noise pollution, alcoholism and sexually transmitted diseases (STDs). The NEES programme is expected to be uncorrelated with the households using only animal dung as a source of energy since they are neither ineligible for the appliance rebate programme nor the energy demand response programme. Similarly, prices of informal dwellings are expected to be uncorrelated with NEES since there is less likelihood that these dwellers in this type of housing would adopt the programme because of the following reasons: most of these type of dwellings are not grid-connected, the dwellers are unlikely to be able to afford the cost of NEES appliances even with the rebate, and most importantly, the physical and socioeconomic conditions of these dwellings and dwellers may not support energy efficiency improvements. Also, noise pollution coming from social activities, busy traffic or local market areas, as well as individuals drinking habits and STDs from indiscriminate sexual experiences would most likely be uncorrelated with NEES. These counterfactual exercises yielded results consistent with null expecta-

tions, thereby raising the confidence bar of the results. Additionally, I explore robustness in alternative clustering of the standard errors, quasi-experimental design and model specifications using probit and two-stage difference-in-differences estimations which further substantiates the internal validity of the recovered causal effects.

Moreover, this study argues the transmission mechanisms of the effect of NEES on the considered outcomes. First, the significant positive effect of NEES on property values is directly explained by the immediate programme adoption, such that the purchase of the NEES recommended appliances would naturally raise property values since it would lead to direct energy performance improvements of the dwellings. Second, the transmission mechanism for the pollution reductions are also explained by the households' adoption of the NEES recommended appliances and the increasing efficiency in the domestic use of grid electricity for lighting, cooking and heating purposes. This technology switch from inefficient to efficient ones, especially in the domestic usage of purchased NEES appliances such as refrigerator, microwave, air conditioners, etc., would lead to environmental pollution reductions, particularly in air, water pollution, littering, land degradation and asbestos exposure. This is because there is longer preservation of food items and clean cooking methods in treated low-income households. Additionally, the use of television by these households may expose them to information on better environmental practice leading to pro-environment behavioural changes towards less littering and land degradation. Similarly, the transmission mechanism of the effect on non-chronic diseases—respiratory infections, diarrhoea and severe TBC are through environmental improvements due to NEES induced pollution reductions in air, water pollution, environmental littering, land degradation, and asbestos exposure. For instance, severe TBC have been found to be both air and water borne. Medical research have linked air and water pollution to the causative-agent of tuberculosis—tubercle bacilli or mycobacterium tuberculosis (Rajaei et al. 2018; Tremblay 2007; Greenberg and Kupka 1957). Moreover, the effect on respiratory disease and diarrhoea are through reductions in air, water pollution, littering, microwave and refrigerator usage (causing improved cooking and food preservations) resulting in possible reductions in the bacteria that causes diarrhoea thus reducing food poisoning. These studies have shown that this bacteria-causing-diarrhoea—Salmonella and Vibrio parahaemolyticus—to be marine based (Kalvaitienė et al. 2023; Wang et al. 2015; Hernroth et al.

2009). Similarly, the virus-causing-diarrhoea—norovirus, rotavirus, sapovirus and astrovirus—have also been linked to contaminated food and water (Sajewski et al. 2022; Mattison et al. 2021; Lopman et al. 2014). Therefore, environmental improvements in air and water pollution would significantly reduce respiratory illness and the presence of either the bacteria- or virus-causing-diarrhoea in treated low-income households.

This study exploits the exogenous variation provided by the NEES programme in South Africa to argue the above contributions. This identification strategy involves the use of only the share of NEES-eligible low-income households. Similar identification strategy has been used by Davis et al. (2014) in Mexico. The TWFE estimates and event study designs is employed to determine the effect of the energy efficiency on the outcomes before and after the roll-out of NEES interventions to low-income households between 2011 and 2012.

This rest of this article is organised as follows. Section 2 discusses a comprehensive literature review on the outcomes. Section 3 discusses the important details about NEES and the identification strategy. Section 4 describes the data used, the data cleaning process and samples, outcome trends and important descriptive statistics. Section 5 presents and discusses the empirical methods and results. Section 6 conducts series of robustness checks on the established results. Section 7 discusses heterogeneous characterizations of the effects. And Section 8 concludes.

2 Literature Review

This section reviews three related strands of literature on energy savings and usage, house prices and rents, and pollution and public health outcomes. It is noteworthy that the literature on rents, and public health outcomes are quite meagre.

2.1 Energy Savings and Usage

For the effect of energy efficiency on energy savings, Fowlie et al. (2018) investigated the Michigan State weatherization programme by encouraging a random sample of the participants, and then used that as

an instrumental variable to compare between those who did and did not receive encouragement. They examined the impact of the residential energy efficiency programme. They found that investment cost in residential energy efficiency is more than twice the cost of actual energy savings. And that model-projected energy savings are more than three-times the actual savings, which is attributed to the increased energy demand given energy efficiency—the rebound effect. Furthermore, they found insignificant rise in room temperature in weatherised homes even after accounting for various societal benefits of reduced emissions. They conclude that the cost of energy efficiency still substantially outweighs the benefits of annual average of -7.8% returns. Likewise, Davis et al. (2014) investigated a large appliance replacement programme in Mexico and its impact on energy use. The government between $2009-2012$ assisted households to replace their old refrigerators and air conditioners to new energy efficient ones. The results showed that appliance replacement (efficient fridge) reduces electricity consumption by 8%, whereas energy efficient air conditioners increased electricity consumption. They concluded that the programme was an expensive way of reducing CO_2 emissions costing $\$500/ton$. Interestingly, Jacobsen and Kotchen (2013) examined the impact of a change in building energy code using residential billing data on electricity and natural gas consumptions in Florida. They exploited the variation of households constructed just before and after building energy code change. The results showed that the code change caused a 4% decrease in electricity consumption and 6% decreases in natural gas consumption. Using a similar identification strategy and extending the same dataset, Kotchen (2017) found significant savings only for natural gas, but the energy savings on electricity consumption due to change in building energy code diminishes over time. Metcalf and Hassett (1999) sought to provide empirical explanation to the energy paradox (consumers are more likely to not embark on energy saving investments) by analysing return of individual projects that consumers undertake. They used the annual residential energy survey and found that the reason for this paradox can be explained by the fact that the realised returns from such investments are usually lower than that promised by engineers. However, their empirical results show that attic insulation investment returns are significant but their median estimate is identical to the discount rate for this investment. They conclude that the case of energy savings investment are weaker than previously believed.

2.2 House Prices and Rents

Indeed, studies that used the causal inference methods to determine house prices documented heterogeneous effects. Some notable methods used include the two-way fixed effect (TWFE), difference-in-differences (DID) and instrumental variable regressions. Adelino et al. (2012) used DID and the exogenous changes in conforming loan limit to instrument lower cost financing, and then examined whether credit access raises house prices in the US. They found that easier credit access has a significant positive impact on house prices by an average of $220 per square foot. Dastrup et al. (2012) used repeat sales identification and TWFE to document a significant solar premium on house prices in California, US. Similarly, Figlio and Lucas (2004) used repeat sales identification to determine whether the school grading system in Florida US affected rental residential location and house prices. They found that the school grading system established by President Bush is capitalised in house prices, with associated premium declining over the years. Grade A-rated schools have more house price capitalisation than B- and C-rated schools, respectively. In Netherlands, Aydin et al. (2020) examined the impact of energy performance certificate on house values using energy prices and repeat sales identification strategies. They used energy prices as identifying instrument exploiting the discontinuity in the evolution of energy prices over time. Their results showed that energy efficiency levels of households are capitalised in house prices. In Australia, Lan et al. (2020) used matching methods to document significant premiums due to solar photovoltaic (PV) installation on residential properties. Qiu et al. (2017) also used matching methods to examine the impact of solar energy systems on house prices in Arizona, US. Their results showed a positive house price premium for houses with solar PV installations but no statistically significant effect on houses with solar heaters alone. Moreover, Kaplan et al. (2020) built a US-based model with multiple aggregate shocks namely, income, housing finance conditions and beliefs about future housing demand, and performed series of counterfactual experiments investigating housing boom around the global financial crisis period. Findings showed that the main drivers of changes in house prices are shifts in beliefs of future housing expectations, whereas shifts in credit conditions are important for the dynamics in homeownership, leverage and foreclosures. Allcott and Greenstone (2012) theoretically investigated energy efficiency gap in the US providing perspective on policy directions. The found that energy efficiency investments are heterogeneous across the US population.

Hence, target energy efficient subsidies will generate larger welfare benefit than a generalised one.

However, Gaur and Lang (2023) using repeat sales variation sought to identify the externality of large-scale utility solar PV installations ($\geq 1MW$) on nearby house prices in Massachusetts and Rhode Island, USA, using DID method. They found that houses within 0.6 miles depreciate by $1.5\% - 3.6\%$ following the construction of the solar array. Similarly, Dröes and Koster (2016) used year of wind turbine's construction and repeat sales exogenous variations, to investigate the impact of wind turbines on house prices in Netherlands. Their results showed that the construction of wind turbines reduces house prices within $2km$ of the site. The plethora of robustness checks reveals that this effect ranges between -0.7% to -3.1%. Further, 10 years after treatment, this negative effect is persistent and statistically significant at -2.2%. Moreover, one of the recent literatures on this subject Ferentinos et al. (2023) used random-forest and DID methods to study the effect of climate policies. The study used the minimum energy efficiency policy established in 2018 as an identification strategy to find that green house gas emissions causes a decline in house prices in England and Wales. They found that policies such as the minimum energy efficiency strategy established in 2018 reduced property values for energy inefficient houses affected by the policy.

Furthermore, some non-causal arguments on the capitalisation of energy efficiency into residential house prices are heterogeneous and mostly focused on Australia, Wales, Portugal, Netherlands, Italy and Belgium (Reusens et al. 2023; Copiello and Donati 2021; Fuerst and Warren-Myers 2018; Fuerst et al. 2018; Chegut et al. 2016; Brounen and Kok 2011). They used sales and tenancy data with a hedonic framework to examine the impact of energy efficiency ratings and performance certificates on house prices. They found that both energy efficiency rating and other sustainability related characteristics increase house prices and rents. The characteristics include heating, cooling and solar power generators. The premiums from energy ratings are more pronounced for houses in bands A and B, than houses in band C. Whereas houses with energy performance certificates in D and later recorded significant discounts. B. Zhang et al. (2023) studied the impact of energy efficiency of buildings on house prices in China using data envelopment analysis and mediation analysis. The results showed that China's energy efficient buildings are rising resulting in a 0.58% increase in house prices. Similarly, Breitenfellner et al. (2015) studied how energy price inflation is a panacea for downward corrections in house prices using data on 18 OECD countries.

They identified such periods of downward house price adjustments. Their results showed that energy price inflation raises the likelihood in the occurrence of such periods in OECD countries. More studies have further argued on the capitalisation of energy efficiency labels into house prices in the US cities (Research triangle region of North carolina, Austin Texas and Portland-Oregan) and Sweden (Walls et al. 2017; Cerin et al. 2014). These results are especially true for newer houses rather than old ones in the US, and those built before 1960 in Sweden. Furthermore, Eichholtz et al. (2010) studied the importance of certification of green building (investment in energy efficiency) on rents, effective rents and sales price of commercial buildings. Their results showed that green buildings raises rent by about 3%, effective rent about 7% and commercial property values by 16% in the US. Taruttis and Weber (2022) studied energy efficiency effect on property values in Germany, and checked for regional disparities. They found that energy efficiency is capitalised into house prices in Germany and evidence of regional disparities, with the effect more pronounced in rural Germany compared to larger cities and other urban areas. Moreover, Williams et al. (2023) using a grid-response and life-cycle approaches examined the impact of electrification of building on housing affordability and environmental sustainability. They found that compared to traditional building energy model, calibrated electrified building model raises energy efficiency which raises housing affordability in the US. Using quantile regressions, Evangelista et al. (2022) found heterogeneity in the elasticity of house prices to energy efficiency over the spectrum of the distribution, and between house types, i.e., houses and flats. While the effect on houses is positive and significant, the effect on flats is negative and significant. Further, the effect is significant and negative for residential buildings whose prices are at the lower end of the spectrum. Dröes and Koster (2021) investigated the effect of wind turbines and solar farms on house prices in Netherlands. The study found a heterogeneous effect on house prices in terms of the height of the wind turbines. While house prices within $2km$ declines due to tall wind turbines $(> 150m)$, small wind turbines $(< 50m)$ raise prices by no more than 2% and dissipates beyond $1km$. Also, they showed that solar farms has a significant negative impact on house prices within $1km$.

Some pioneering studies that generally looked at the determinants of house prices include Richardson et al. (1974), Peng and Wheaton (1994) and Capozza et al. (2002). These studies used OLS and spatial models with hedonic controls to conclude on the capitalisation of a number of factors into house prices, especially

in Asia, United Kingdom and the United States. They found that land scarcity raises house prices which are capitalised into rents. Furthermore, they recorded no evidence of any location-based theory on house prices, rather, housing characteristics, spatial variables, accessibility and environmental quality conditions. Similarly, household income and cost of construction, have significant positive impact on house prices. In Singapore, Fan et al. (2006) examined the relationship between house prices and housing characteristics. The results showed that number of rooms, size of the floor area, age of house, recreational facilities and the living environment increases house prices. Using AirBnB and NewYork open data, Bernardi and Guidolin (2023) studied the price determinants of AirBnB rentals in NewYork. They found that property and service characteristics have significant influence on rental prices. Eriksen and Ross (2015) estimate the supply of increasing housing vouchers on rents in the US. They found no significant effect of voucher increases on overall rents, but a significant effect were found for individual housing unit before the voucher expansion. Further, voucher recipients tend to rent higher expensive houses. Using census data, Gilderbloom and Appelbaum (1987) examined the determinants of rents in the US urban areas. Their results showed that social forces such as the professionalisation of the rental housing industry (organisation by landlords) is a more important determinant of rents than supply and demand factors.

In the macroeconomics literature, Ling et al. (2015) examined the role of market non-fundamental-based sentiments (home buyers, home builders and creditors) on house price dynamics. They found that market non-fundamentals (housing market sentiments) have a more substantial positive effect on house prices, than the market fundamentals. Likewise, Kuchler et al. (2023) studied the determinants of housing market expectations. They found the recent house price, personal experiences, information of close friends, house prices in close social networks, and current homeownership status all influence housing market expectations. In OECD countries, Hirata et al. (2013) found that global monetary policy shocks (interest rate) do not have any sizeable impact on global house prices in advanced economies, but output shocks have a modest impact on global house prices. In Canada, Allen et al. (2009) studied the longrun relationship between Canadian city house prices and city-specific variables such as union wage levels, interest rate, and building permits. The results show no cointegration in average house prices with city-specific variables. They suggested an investigation on house price variation at the village or municipal level. The results

further show that union wage and permits raise house price, while interest rates exerts a negative effect in the short-run. Similarly, Goda et al. (2020) studied the effect on income inequality on house prices in OECD countries, using the Solt's standardised World Income Inequality Database. They found that absolute income inequality raises house prices both in the short- and long-run, whereas, relative income and real interest rate have no long-run impacts. In Namibia, Sunde and Muzindutsi (2017) examined both the endogenous and exogenous determinants of house prices in Namibia's housing market. They found that increases in population, mortgage loans and inflation raise house prices, while aggregate demand and inflation raise housing supply in terms of construction of new homes. Similarly, Bakens and De Graaff (2020) found that share of immigrants into a small area have a significant positive impact on house prices in Netherlands. In China, Tan et al. (2019) investigated the multi-level determinants of house prices and their interactions at different levels. The results showed an increase in the average house price due to accessibility factors and multi-level socioeconomic factors in China. These factors include high-way speed train, rural-urban migration, per capita living space and urban employment.

2.3 Pollution and Health Outcomes

The pollution reduction effects given energy efficiency improvements have been advanced in the engineering literature. This is documented in the works of S. Zhang et al. (2014) and S. Zhang et al. (2015) which recorded air pollution (e.g., carbon emissions (CO), particulate matter $(PM_{2.5})$, sulphur (SO_2) and nitrogen oxide (NO_2) emissions) reduction effect in the Chinese cement, and iron and steel industry using greenhouse gas, and air pollution interactions and synergies model. This environmental gains culminate into public health benefits as proposed in the seminal work of McDermott (1961). Chinese authors have further documented pollution reductions and public health benefits (reduced morbidity rates) due to a cost-effective energy efficiency improvements in the cement industry. Similarly, Kearns et al. (2023) studied the impact of home energy efficiency programme (external wall insulation) on self-reported health scores, and hospital admissions in Scotland. They found that improved thermal comfort increased self-reported physical health and reduced hospital admissions for up to five years after thermal wall insulation, which is more pronounced for respiratory than cardiovascular illnesses.

Conversely, many studies have documented worsened health conditions (respiratory illnesses—bronchitis, lung cancer—morbidity and mortality rates) of rising air pollutions in both adults and children (Hertz-Picciotto et al. 2007; Raizenne et al. 1998; Bates 1995; Lave and Seskin 1970). Singh et al. (2018) using logit model examined the determinants of the self-reported incidents of tuberculosis (TB) in India. They documented that individuals who smoke or exposed to indoor second-hand smoking, and shared toilets are more vulnerable to TB, whereas, individuals having portable water, use of modern cooking fuels, have improved flooring, wall and roofing are less likely to suffer from TB. Rajaei et al. (2018) using geographic information systems modelling found that higher air pollution ($PM_{2.5}$ and CO) in Tehran is positively associated with increased prevalence of TB. Lin et al. (2007) conducted a meta-analysis on how tobacco smoking, passive smoking and indoor air pollution influences TB. Their findings reveal that smokers (compared to non-smokers) are more likely to have or be dying from TB diseases. Moreover, they documented that passive smoking and indoor air pollution insignificantly increased incidents of TB.

The studies presenting causal evidence on the public health benefits of pollution reductions further foregrounds the significance of energy efficiency improvements. Chay and Greenstone (2003) used sharp, differential air quality changes across sites attributable to geographic variation in the effects of the $1981-82$ recession to estimate the causal impact of particulates air pollution on infant mortality in the US. They found that reductions in particulates air pollution caused a reduction in infant mortality. Similarly, Currie and Neidell (2005) used fixed-effect regression to study the impact of air pollution on infant mortality in California using three criteria pollutants (SO_2, NO_2 and CO). Their results showed that decreases in air pollution saved about 1000 lives. Moreover, Greenstone and Hanna (2014) exploited the environmental policy changes effected by the supreme court in India in a difference-in-differences framework to investigate the effect of environmental regulations on air and water quality on infant mortality in India. Their results showed that improvements in air quality caused statistically insignificant decline in infant mortality while the effect of water quality improvement is negligible. Concomitantly, Sheldon and Sankaran (2017) used fixed-effect model and exploits the exogenous variation provided by Indonesian forest fires to study the trans-boundary health effects in Singapore. They found that forest burning significantly raises air pollution which in turn increases the polyclinic admissions and attendance for acute respiratory infection,

conjunctivitis, lung diseases, asthma, bronchitis, emphysema and pneumonia, etc. Likewise, Schlenker and Walker (2016) used the exogenous variation in excess airplane idling (airport congestion) measured as residual daily taxi time in airports to study the effect of CO emissions on health outcomes such as asthma, respiratory and heart-related energy rooms admissions in California. They found significant increase in hospitalisation costs for asthma, respiratory and heart-related admissions for residents within $10km$ of the airport. They further showed that this effect persists in CO levels far below the regulatory standard.

3 NEES and Identification

The implementation of the NEES programme commenced in 2005 (*The National Energy Efficiency Strategy* 2005) to champion efficiency improvements in energy demand, especially amongst the middle- and high-income households, who are regarded as the heavy consumers from the outset; and later, low-income households as they get connected to the grid. The NEES programme is the largest energy efficiency programme in South Africa and has the mandate to increase energy efficiency in all economic sectors (*The National Energy Efficiency Strategy* 2008; *The National Energy Efficiency Strategy* 2005). The authority to undertake the strategy comes from the South African Constitution, the National Energy Act 2008 and the South Africa's White Paper on Energy Policy 1998. [3] It has an estimated budget of over $R100$ billion over a ten-year period. The core objectives are to combat pollution on health grounds, and to enforce standards for housing and labelling/efficiency standards for household appliances. To achieve these objectives, NEES uses enabling instruments and interventions. Generally, they include inter-alia, economic and legislative means, efficiency labels and energy performance standards, energy management activities and energy audits, as well as the promotion of efficient practices. Given the successes of NEES implementations, the $post-2015$ NEES was established to consolidate the success as discussed in Section 1, and to further meet their new energy efficiency target by 2030 (*1st Draft: Post-2015 National Energy Efficiency Strategy* 2015). The consolidated objectives are to transform household appliance market in favour of en-

[3] Hitherto to the White Paper on Energy Policy of 1998 in South Africa, energy use in most households came from less convenient and unhealthy sources (*White Paper on the Energy Policy of the Republic of South Africa* 1998). Further, energy services by previous governments focused on creating an industrial urban society to meet the needs of the industrial sector, affluent and white-minority households. Importantly, previous energy policies have not addressed the energy conservation needs of high-income grid-electricity-dependent households. Some of these major energy policies include the Integrated Energy Planning of 2002, Free Basic Electricity Programme of 2003, National Electricity Regulator Act of 2004 and the National Energy Act of 2008. Hence, the White Paper provides a broad framework for the subsequent development and implementation of government energy efficiency policies for all households by income groups. This was aimed at ameliorating the negative health impacts from the use of certain traditional fuels and reducing energy related emissions that are harmful to the environment and human health. The NEES programme 2005 focused on energy efficiency improvements in all South African economic sectors.

ergy efficient models reducing their energy consumption by 33%, and to increase the energy performance of new residential buildings by 20%.

NEES implements both low-cost and no-cost interventions, as well as higher-cost measures with short payback periods for grid-electrified households only. The implementation of NEES interventions first prioritised high-income households between $2005 - 2008$ as they were considered heavy energy users. After the first official review of the strategy in 2008, priority extended to middle-income households from 2009 onwards. [4] By the end of the second official review in 2011, priority further extended to the low-income households, including those low-income households newly connected to the grid. Post-2015 NEES consolidates on the achievements and implementation strategies of its predecessor. It is still currently running and geared towards achieving its 2030 target. The NEES interventions were implemented in two phases for each income group in different years between 2005 and 2021. Phase one involved an energy audit programme using qualified energy auditors to identify areas of potential energy savings in households, mandatory labelling of households and market appliances using established standards, raising awareness to communicate the cost-benefits of energy efficiency in the home and mandatory standards for newly constructed state-subsidised housing commencing in 2006. Phase one prioritised grid-connected high-income households with ownership of any of the NEES recommended appliances. In phase two, the South African DoE through Municipalities and Service Authorities financed the rolling out of energy efficiency retrofit programmes (commencing in 2008) to grid-electrified households that own any of the NEES recommended appliances in all the nine Provinces in South Africa, prioritising the middle-income households. In 2011, priority shifted to low-income households. These programmes include Appliance Rebate Programme and Energy Efficiency Demand Response Programme. In the appliance rebate programme, subsidy was offered by the DoE to encourage households who purchased any energy-efficient NEES recommended appliances to purchase more. The interventions were rolled out on a monthly and annual basis from 2008 and ran until 2015 for middle-income households, and from 2011 onwards for the low-income households. It offered rebates of up to $R6,000$ (about 400 US dollars) to each household to purchase more energy efficient appliances conditional on the cost of any energy efficient appliances currently owned by the household. These

[4] The Department of Energy (DoE) in South Africa reviewed the strategy at the end of every third-year of implementation, during which an appraisal and measurement of the energy efficiency strategy were performed.

recommended appliances include energy-efficient lighting bulbs, television (TV), radio, fridge, freezer, tumble-dryer, washing machine, microwave, air conditioner, dishwasher, home theatre and stereo. To be eligible for a rebate, households must meet this condition: households must use grid electricity for their domestic energy consumption and purchased any NEES recommended appliances that met the minimum energy performance standards set by the DoE. The appliances also had to be purchased from a participating retailer. On the other hand, the Energy Efficiency Demand Response Programme was a demand-side management programme implemented by the DoE aimed at reducing peak demand of electricity by encouraging grid-connected households to reduce their energy consumption during peak times. The programme offered financial incentives to households that reduced their energy consumption during peak times. The incentives were based on the amount of energy saved and the time of day when the energy was saved.

Given the foregoing, I identify the eligible households (hereafter, treated group) to be the low-income households who either own any of the NEES recommended appliances, deliberately reduced their energy consumption during peak demand, or exhibit energy efficiency behaviours (such as switching off their appliances or lights after use or before leaving their homes) because they are connected to the grid and use it for domestic purposes, such as lighting, cooking and heating (water and space). The ineligible households (hereafter, never-treated group) comprise of the following households: (i) Those households without grid connection and grid usage but either own energy inefficient appliances, reduced their energy consumption, or exhibit energy efficiency behaviours. These households use alternative energy sources such as mechanical electricity generator, and/or crude energy sources such as animal dung, paraffin and gas. (ii) Those households who neither have grid connection nor use grid-electricity, and neither own any of the NEES recommended appliances, reduced their energy consumption during peak demand, nor exhibit energy efficiency behaviours. In sum, the never-treated group are households without grid connection and grid usage, whether or not they own any of the NEES recommended appliances, reduced their energy consumption during peak demand, or exhibit energy efficiency behaviours. This group is further grouped into low-, middle- and high-income households, with the low-income households. The roll-out of the NEES programme for low-income households starting in 2011 provides grounds to make a reasonable assumption about when at least one low-income household was treated given the NEES eligibility conditions. Because

of its staggered implementation, there exists at least a recently grid-connected low-income household that would comply with NEES conditions and become treated between 2011 and 2012. Hence, the treatment dates are set to be from 2011 to 2012 to capture all NEES treated low-income households. [5]

4 The Data

The data used is the annual generalised household survey (GHS) provided by the Statistics South Africa, the most comprehensive household survey in South Africa (StatisticsSouthAfrica 2021). The GHS data was designed to measure the living standards of South Africans. The cross-sectional coverage of the survey are all de jure households and residents in workers' hostels in all the nine provinces. [6] The survey used probability proportional to size to draw a multi-stage stratified sample of households guided by their census master plans. The first stage is stratification by province, then by type of area within each province. Primary sampling units are then selected proportionally within each stratum (urban or non-urban) in all provinces. The information in this dataset are self-reported responses to the survey questions. The annual cross-sections of this GHS datasets were stacked into a repeated cross-sections. Following the various South African censuses in 1996, 2001 and 2011, household and individual weighting were applied over these periods for comparability across samples accounting for compositional changes. The stacked sample has a total sample of $2,518,460$ observations over $2005-2018$. [7]

4.1 Data Cleaning Process

The $14-years$ sample contains all the comparison groups—the treated, the never-treated and the eventually-treated household groups. Given that grid electrification of low-income households stopped and switched to solar electrification starting in 2013, this means that the NEES treatment were administered to eligible grid-using low-income households from $2011-2012$. Hence, all solar electrified households were re-

[5] Given that not all low-income households are either grid connected, use grid connection or own any NEES recommended appliances, and not all with grid connection own any NEES recommended appliances as at 2011, it suggests a non-constant treatment timing on treated low-income households between 2011 and 2012. As a remark, in South Africa, solar electrification programme replaced grid electrification for all low-income households not connected to the grid due to their long distance away from the grid distribution stations. The solar electrification programme began in 2013, called the New Household Electrification Strategy. Thus, the NEES treatment applies to only those low-income households already connected to the grid by the $31st$ of December 2012.

[6] The survey does not cover collective living quarters such as students' hostels, old age homes, hospitals, prisons and military barracks.

[7] Treatment is defined based on the NEES eligibility conditions discussed in Section 3. The GHS dataset used for this study do not have information on the energy performance standards of household appliances. Thus, given the discussed eligibility criteria, it is logical that the component of the never-treated households that are not connected to the grid whether or not they own any appliance, are more likely to own and use energy inefficient ones. Invariably, the treated low-income households are most likely to own energy efficient appliances because they use grid connection for their domestic purposes. The target of households with domestic grid usage is to aproximate South African households that actually consume electricity supply from the grid. This way, I avoid those households that may have grid-connection status without actual supply of electricity to their homes.

moved from the dataset, resulting in about 1.84% shrink in the sample. Further, all the eventually-treated households were removed. That is, all households with grid electricity connection and uses grid electricity supply for their domestic purposes but do not yet meet NEES eligibility conditions by the end of the dataset period. This shrank the sample by an additional 5.32%, totalling to a 7.16% reductions, resulting to a total sample of $2,338,252$ observations as my final sample. This sample thus contains only the treated and never-treated households as defined in Section 3 with $114,197$ unique households, $12,049$ unique villages and all nine provinces in South Africa. This forms a representative sample of households-by-villages-by-provinces-by-year pair observations. Using the definitions of households income groups in the 2011 South African census, I group the sample into low-, middle- and high-income households (2015). [8] This grouping allows for the comparison of the treated low-income households to the never-treated households without domestic grid usage whether or not they either own any NEES appliances, deliberately reduced their energy consumption or exhibit energy efficiency behaviours.

To study the individual outcomes, I subset the data to the following groups, comparing the treated low-income households to the following never-treated groups: low-income; middle-income; low- and middle-income; low- and high-income; middle- and high-income; and finally low-, middle- and high-income households. Thus, the sample sizes for the study on the effect of the NEES programme on the housing market and pollution outcomes is the same for all the comparison groups. That is: (i) $903,655$ for the treated low-income vs. never-treated low-income households; (ii) $872,646$ for the treated low-income vs. never-treated middle-income households; (iii) $980,142$ for the treated low-income vs. never-treated low- and middle-income households; (iv) $905,973$ or the treated low-income vs. never-treated low- and high-income households; $874,964$ for the treated low-income vs. never-treated middle- and high-income households; and (v) $982,460$ for the treated low-income vs. never-treated low-, middle- and high-income households. However, to study the effect of the NEES programme on health outcomes, I restrict the whole sample to range from $2005-2015$ due to significant missingness in the health variables possibly due to non-responses. This restriction allows the avoidance of external bias in the causal estimations due to missingness, with total health sample of $1,245,338$. Consequently, the comparison sample sizes for the

[8] Low-income households are those whose monthly income is, $I \leq R1600$, middle-income households earn between $R1601 \geq I \leq R25600$, and high-income households earn $R25601 > I$. Thus the ranges by 12 gives the annual household income realisations.

health outcomes are as follows: (i) $378,603$ for the treated low-income vs. never-treated low-income households; (ii) $339,041$ for the treated low-income vs. never-treated middle-income households; (iii) $3398,807$ for the treated low-income vs. never-treated low- and middle-income households; (iv) $378,763$ or the treated low-income vs. never-treated low- and high-income households; $339,201$ for the treated low-income vs. never-treated middle- and high-income households; and (v) $398,967$ for the treated low-income vs. never-treated low-, middle- and high-income households. Finally, within this comparison groups, I further narrow in and compare the treated low-income households to the two subgroups of the never-treated households. That is, the never-treated households who either own NEES recommended appliances, reduced their energy consumption or exhibit energy efficiency behaviours, and the never-treated households who do not.

4.2 NEES Treated Households and Trends in South Africa

Figure 1 plots the trends of NEES compliant households in panel A, and property values and rents in panels $B-C$, and pollution and non-chronic morbidity in panels $D-E$. Panel A shows the evolution of low-income households with domestic grid usage and either own any of the NEES recommended appliances, reduced their energy consumption during peak demand, or exhibit energy efficiency behaviours before and after the initial treatment dates. In the pre-treatment periods, there appears to be a largely parallel evolution between household groups until 2009 when South Africa witnessed a national economic recession following the global financial crisis in 2008. This cumulative economic shock accounts for the decline in trends of NEES compliant households (blue line) which returned to pre-crisis levels in 2010. This decline reflects and mirrored a rise in the never-treated low-income households (red line) in that period. Similar trends are observed in panels $D-E$ for the pollution and non-chronic morbidity outcomes. Between $2011-12$, there is a clear deviation in trends in NEES compliant households for the treated relative to the never-treated low-income households, and maintained an upward trend until 2018. This suggests a gradual and positive adoption of the NEES programme by low-income households since treatment commenced. Similar post-treatment trends are observed in panels $B-C$ for property values and rents disregarding the undulating nature of these trends. For the panel $D-E$, there is a noticeable declining trends in the

pollution and non-chronic morbidity outcomes in the years following the initial treatment.



Figure 1: Outcome Trends between the Treated and Never-Treated Low-Income Households

NOTES: This figure compares the treated low-income households (blue lines) to the never-treated low-income households (red lines). Panel A plots household domestic grid usage and NEES programme adoption in terms of NEES recommended appliances such as energy efficient light bulbs, television (TV), radio, fridge, freezer, tumble-dryer, washing machine, microwave, air conditioner, dishwasher, home theatre and stereo. The first NEES treatment of low-income households started in 2011. Some households within a village in South Africa are treated in 2011 and others in the same village are treated within the first quarter of the next year as they get connected to the grid. Hence, the treatment window is set to $2011 - 12$. Panels $B - G$ compare housing market (homeowners, renters, property values, rents), pollution and health (illness) outcomes between the treated and never-treated low-income households.

4.3 Descriptive Statistics

The descriptive statistics are reported in Table 1 and the summary statistics of the pre-treatment covariates between the treated and the never-treated households before and after the treatment are reported in Table 58 of Appendix I. Table 58 shows that the pre-treatment covariates are largely balanced in both the treated and the never-treated groups before and after the treatment. Table 1 reports that the there are more Blacks than Whites in the sample, with an average age of 29 years. There are also more females and married low-income individuals living in more urbanised non-metro areas. Most of the residential locations of the observations are farther away from school, traditional toilet facilities and local water sources. This is due to higher number of them living in more modern houses and have water piped into their dwellings. The average number of rooms in these houses is 5 rooms, and many them do not have land access.

Table 1: Descriptive Statistics for Low-Income Households

Variable	Mean	Std	Min	Max
Age	29.178	20.568	0	113
male	0.468	0.499	0	1
married	0.246	0.431	0	1
black	0.871	0.335	0	1
white	0.047	0.212	0	1
metro area	0.308	0.462	0	1
rural area	0.166	0.372	0	1
house proximity to school	0.241	0.428	0	1
house proximity to toilet	0.053	0.224	0	1
house proximity to water source	0.316	0.465	0	1
piped water into dwellings	0.624	0.484	0	1
Traditional dwellings	0.112	0.315	0	1
households' land access	0.024	0.153	0	1
number of rooms	5.212	2.762	0	60
households' domestic grid usage	0.076	0.265	0	1
nees appliance ownership due to grid	0.150	0.357	0	1
monthly rents	469.944	320.694	100	1501
estimated market house prices	149487.721	161806.473	40000	1000000
monthly house rents (log)	5.938	0.669	5	7
estimated market house prices (log)	11.475	0.886	11	14
pollution	0.628	0.483	0	1
air pollution	0.471	0.499	0	1
water pollution	0.271	0.444	0	1
littering	0.592	0.491	0	1
land degradation	0.016	0.124	0	1
asbestos	0.091	0.288	0	1
non-chronic morbidity	0.346	0.476	0	1
respiratory infection	0.019	0.137	0	1
severe tuberculosis	0.335	0.472	0	1
diarrhoea	0.009	0.092	0	1
mental illness or depression	0.006	0.075	0	1

Interestingly, domestic grid usage of these low-income households is only 7.6%, with only 15% of grid connected households owning NEES recommended appliances. The housing market statistics shows that the average rent is approximately $R470$ per month, and the estimate market house prices is approximately $R149,000$. About, 63% of the low-income households reported that pollution is an environmental problem, especially in terms of air (47%), water (27%), littering (59%), asbestos exposure (9%) and land degradation (2%). Furthermore, about 35% of the individuals reported that they suffer from at least one non-chronic

morbidity, particularly respiratory infections (2%), severe tuberculosis (34%), diarrhoea (1%) and mental illness (1%).

In what follows, I present the empirical strategies and further discuss the results on the causal impacts of NEES on the outcomes.

5 Empirical Methods and Results Discussion

5.1 Empirical Methods

Given the staggered implementation of NEES, I apply the TWFE method to a staggered quasi-experimental design. I use both the TWFE estimates and event studies to determine the effect of NEES on the outcomes. Previous studies have followed this process (Cengiz et al. 2019; Dröes and Koster 2016; Jacobsen and Kotchen 2013). I follow Cengiz et al. (2019) and Borusyak et al. (2021) procedures to specify the following model.

$$\begin{aligned} Z_{j,h,v,p,t} = \beta_1 Treated^{e}_{h,v,p,t} + \beta_2 Grid_{h,v,p,t} + \beta_3 DU_{h,v,p,t} + \beta_4 NEESAPP_{h,v,p,t} \\ + \beta_5 LincH_{h,v,p,t} + \phi P_{j,h,v,p,t} + \omega H_{h,v,p,t} + \lambda_t + \delta_p + \theta_{p,t} + \varepsilon_{j,h,v,p,t}, \end{aligned} \tag{1}$$

where $Z_{j,h,v,p,t}$ is the vector of outcomes; for example, energy efficiency (programme) adoption and grid electricity usage, housing market outcomes (property values and rents), pollution outcomes (littering, air and water pollution, asbestos usage land degradation), and non-chronic morbidity (respiratory infection, diarrhoea, tuberculosis, and mental illness or depression) in South Africa for an individual, j, in a treated low-income household, h, in village, v, in province, p, in year, t. $Treated^{e}_{h,v,p,t} = \mathbf{1}[t - G_{h,v,p,t} = e]$ denotes treated low-income households being e periods away from the initial treatment date, $G_{h,v,p,t}$. It is a dummy interaction for low-income households, $LincH_{h,v,p,t}(0,1)$, who are treated if they have grid connection, $Grid_{h,v,p,t}(0,1)$, use electricity for domestic purposes, $DU_{h,v,p,t}(0,1)$, such as either lighting, cooking or heating, and either own any NEES recommended appliance, deliberately reduced their energy consumption during peak times or exhibit energy efficient behaviours, in terms of switching off their appliances after

use or when leaving their house, $NEESAPP_{h,v,p,t}(0,1)$. This interaction follows the NEES programme treatment conditions discussed in Section 3. $P_{j,h,v,p,t}$ is a vector of the individual and geographic dummy variables including individual's age, gender, marital status, race and locations (metro and rural). $H_{h,v,p,t}$ is the vector of hedonic characteristics such as household dwelling's proximity dummies to water source, toilet facility and school, water piped into dwelling, number of rooms, land access and beneficiaries of the housing subsidy programme. The hedonic controls are standard in the housing market literature (Ferentinos et al. 2023; Gaur and Lang 2023; Dröes and Koster 2021; Goda et al. 2020; Kaplan et al. 2020; Tan et al. 2019; Fowlie et al. 2018; Fuerst et al. 2018; Dröes and Koster 2016; Adelino et al. 2012; Dastrup et al. 2012; Choy et al. 2007; Fan et al. 2006; Capozza et al. 2002; Peng and Wheaton 1994; Richardson et al. 1974). I further control for year and province fixed-effects, λ_t and δ_p, to adjust for the average of time varying unobservable factors (for example, the global financial crisis, the South Africa's economic recession of 2009, the national housing financing programmes in South Africa in 2010 and the loading shedding policy in 2014, etc.), and within provinces permanent differences that may have influenced NEES programme implementation such as location of each household or village and distance between each household and each village, and socioeconomic differences across households and villages. Moreover, I control for year-by-provinces linear trends, $\theta_{p,t}$ to account for the nationwide evolution of the NEES implementation. I cluster standard errors by provinces to account for the possibility that the changes in the outcomes given the rollout nature of the NEES implementation may be correlated within a province. To increase confidence in the precision of the standard errors as well as the estimates, I apply a one-way cluster robust and bias-correction bootstrapping to equation 1, reporting results after 1000 replications (Cameron et al. 2011; 2008). I show the consistent standard errors, median coefficients, 95% confidence intervals and associated t-statistic.

As the treatment variable, $Treated^{e}_{h,v,p,t}$, is an interacted dummy, the causal parameter of interest is β_1 measuring the difference in the effect of NEES on the vector of outcomes for the treated low-income households relative to either never-treated low-, middle- and high-income households. This parameter measures the intent to treat (ITT) of NEES on the vector of outcomes for the treated low-income households. In the event study results, it captures the difference in the NEES effect on the vector of outcomes

given different lengths of exposure to the treatment, where $2005 \leq e \leq 2018$ but $e \neq 2010$. Additionally, the sum of β_1 and the parameters of the interacting dummies, $\sum_{m=1}^{4} \beta_m$, measures the overall effect of NEES on the outcome for the treated low-income households relative to either never-treated low-, middle- and high-income households. This allows for the separation of NEES from grid electrification programme and usage effects on the outcomes. The difference-in-differences identification of the causal impact of NEES on the outcomes is predicated on a weaker parallel trends assumption. That is, without the interventions, the outcomes between the treated and never-treated households, before and after the treatment, would have evolved in parallel conditional on the foregoing set of pretreatment covariates. Albeit, this assumption is not directly testable, I explore a number of counterfactual exercises using price of informal dwellings, monthly rents less than the low-income group's average, urban noise pollution, STDs and alcohol illness. It is unlikely for NEES to be correlated with the prices of informal dwellings or monthly rents less than the low-income group's average, because such dwellings are unlikely to be grid connected, and their socioeconomic characteristics may pose affordability issues. Similarly, urban noise pollution from social or business activities, individual's drinking habits and STDs from indiscriminate sexual experiences are likely to be uncorrelated with NEES. The results from these counterfactual exercises boost the internal validity of our main results. Additional robustness checks are implemented ranging from pre-trends testing on the outcomes, investigating potential issues of selection into treatment, alternative clustering of standard errors and using of alternative specifications (probit and two-stage differences-in-differences) and experimental design to increase the confidence in the recovered causal effects on the outcomes.

5.2 Programme Adoption and Domestic Grid Usage

In this subsection, I show the effect of NEES on energy efficiency adoption by low-income households as well as their usage of the grid electricity for domestic purposes. The results in Table 2 show a significant increase in energy efficiency adoption for low-income households by a size 1.82 percentage points. This effect subsists in different specifications and after controlling for the fixed effects, after 1000 bootstrap replicates. Overall, NEES increased energy efficiency adoption in South Africa from $15 - 16.82\%$.

Table 2: Effect of NEES on Energy Efficiency Adoption

NEES Adoption	1	2	3	4
treated	0.0165	0.0187*	0.0182*	0.0182*
	(0.0094)	(0.0087)	(0.0096)	(0.0021)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	901,592	901,592	901,592	901,592
R^2	0.0823	0.0901	0.0937	0.0937
Within R^2	0.0712	0.0650	0.0652	0.0652
Bootstrap t-stat	#	#	#	8.6494
Bootstrap-t $CI(95\%)$	#	#	#	[5.152, 15.779]
Baseline Mean	0.150	0.150	0.150	0.150

NOTES: The Table is obtained from estimating equation 1. It compares energy efficiency adoption between the treated low-income and the never-treated low-, middle- and high-income households. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. NEES adoption is a dummy that is unity if a household is connected to the grid and own any NEES recommended appliance, deliberately reduced their energy consumption or exhibit energy efficiency behaviours, and zero otherwise. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Similarly, Table 3 show a significant increase in domestic grid usage for low-income households by $0.9ppts$. This effect also subsists in different specifications and after controlling for the fixed effects, after 1000 bootstrap replicates. The results suggests an increase in domestic usage of grid electricity for low-income households for every $1.82ppts$ increase in energy efficiency adoption. That is, it shows an increasing energy efficiency with increasing domestic grid consumption. Thus, the NEES programme increases domestic grid consumption for low-income households from $7.6 - 8.5\%$. These results are consistent with (Fowlie et al. 2018) which concludes on the rebound effect from the US weatherization programme.

Table 3: Effect of NEES on Domestic Grid Usage

Domestic Grid Usage	1	2	3	4
treated	0.0126**	0.0119**	0.0091*	0.0091*
	(0.0051)	(0.0049)	(0.0046)	(0.0017)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	871,485	871,485	871,485	871,485
R^2	0.0677	0.0725	0.0741	0.0741
Within R^2	0.0590	0.0532	0.0529	0.0529
Bootstrap t-stat	#	#	#	5.4914
Bootstrap-t $CI(95\%)$	#	#	#	[2.969, 11.339]
Baseline Mean	0.076	0.076	0.076	0.076

NOTES: The Table is obtained from estimating equation 1. It compares domestic grid usage of the treated low-income to the never-treated middle- and high-income households. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. Domestic grid usage is a dummy that is unity if a grid connected household uses the grid electricity supply for domestic purposes such as heating, cooking and lighting purposes, and zero otherwise. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Further, Figure 2 reports the dynamic effect of NEES on energy efficiency adoption and domestic grid usage. It shows that the effect of NEES on adoption became significant in the third year of post treatment and persists in the long-run, up to eight years after the treatment date. Similarly, the dynamic effect on domestic grid usage became significant in the fourth year of post treatment and persists in the long-run, up to eight years after the treatment date. There is no evidence of significant pre-trends.

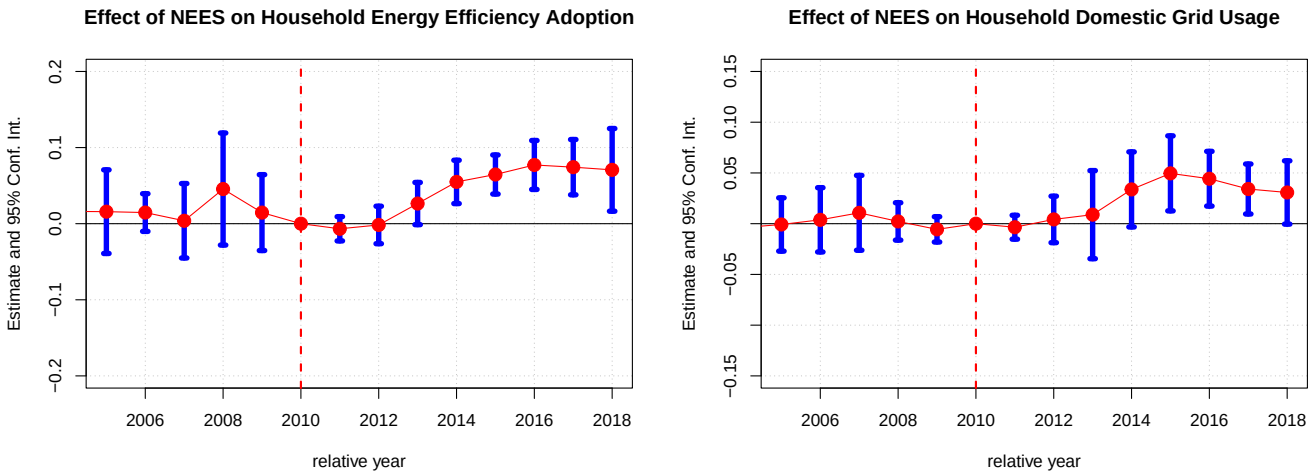


Figure 2: Event Study Plots of the Effect of NEES on Energy Efficiency Adoption and Domestic Grid Usage

NOTES: This figure is obtained from estimating Equation 1 and compares the effect of NEES on domestic grid usage for treated low-income to the never-treated middle- and high-income households. The effect on energy efficiency adoption is compared to a subgroup of the never-treated low-, middle- and high-income households without grid connection and do not own NEES recommended appliances. All equations are quadratic in number of rooms. Energy efficiency adoption is a dummy that is unity if households either own NEES recommended appliances, reduced their energy consumption during peak demand or exhibit energy efficiency behaviours, because of their grid connection and zero otherwise. Household domestic grid usage is a dummy that is unity if a household has a grid connection and uses it for domestic activities such as heating, cooking and lighting purposes, and zero otherwise. Robust standard errors are clustered at the province level.

5.3 Effects on House Prices and Rents

Here, I document the causal effect of NEES on property values and monthly rents of modern houses and flats. The results on the effect on house prices are reported in Tables 4 and 5. Table 4 shows that NEES has a significant and positive effect on property values, and remained stable across different specifications controlling for within within provincial differences. Numerically, NEES raises property values by a size of $3.32ppts$, and remained significant after 1000 bootstrap replicates. Thus, property values of low-income houses and flats increased from $11.48 - 14.81\%$. In the monetary terms, property values increased by $R6,619/annum$ (see Table 5). These results are in line with literatures using similar identification strategy (Aydin et al. 2020; Lan et al. 2020; Qiu et al. 2017) which conclude on capitalization of energy efficiency on house prices in developed countries.

Likewise, Table 6 reports the results on above-average monthly rents. It shows that NEES has a statistically significant and positive effect on monthly rents and was stable across different model specification and controlling for provincial fixed effects. Specifically, NEES raised monthly rents by a size of $8.03ppts$ and remained significant after 1000 bootstrap replicates. This translates to an increase of $R51.64/month$,

increasing above-average monthly rents of houses and flats from $5.94-13.97\%$ for low-income households. This result is consistent with Eichholtz et al. (2010) which document significant positive effects of energy efficiency (using variation in green buildings) on rents in the US.

Similarly, Figure 3 reports the dynamic effect of NEES on house prices and monthly rents. I find that house prices began to significantly rise from the fourth year of initial-treatment date and persists in the long-run, reaching a size of $12ppts$. I document similar results for monthly rents, that was significant beginning from the third year of post-treatment and persists in the longrun, reaching a size of $21ppts$. Indeed, the results show that energy efficiency is significantly capitalized in the housing market. These effects on the housing market are entirely transmitted through the significant adoption of energy efficiency by low-income households in terms of ownership of NEES recommended appliances.

Table 4: Effect of NEES on House/Flat Prices (log)

House Price (log)	1	2	3	4
treated	0.0328**	0.0353**	0.0332*	0.0332*
	(0.0136)	(0.0138)	(0.0157)	(0.0125)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	559,124	559,124	559,124	559,124
R^2	0.3301	0.3443	0.3478	0.3478
Within R^2	0.3148	0.2837	0.2839	0.2839
Bootstrap t-stat	#	#	#	2.6659
Bootstrap-t $CI(95\%)$	#	#	#	[0.618, 4.696]
Baseline Mean	11.475	11.475	11.475	11.475

NOTES: The Table is obtained from estimating equation 1. It compares logged houses/flats property values for treated low-income to a subgroup of the never-treated low- and high-income households without grid connection but own NEES recommended appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. House prices is a self-reported time series of estimated market house prices. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 5: Effect of NEES on House/Flat Prices

House Price	1	2	3	4
treated	6,409.4**	7,322.1**	6,619.1*	6,619.1*
	(2,536.2)	(2,583.3)	(2,967.8)	(2449.9)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	559,124	559,124	559,124	559,124
R^2	0.3201	0.3345	0.3387	0.3387
Within R^2	0.3114	0.2758	0.2767	0.2767
Bootstrap t-stat	#	#	#	2.7018
Bootstrap-t $CI(95\%)$	#	#	#	[0.544, 4.870]
Baseline Mean	149488	149488	149488	149488

NOTES: The Table is obtained from estimating equation 1. It compares houses/flats property values for treated low-income to a subgroup of the never-treated low- and high-income households without grid connection but own NEES recommended appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. House prices is a self-reported time series of estimated market house prices. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 6: Effect of NEES on House/Flat Monthly Rents (log)

above-average rents (log)	1	2	3	4
treated	0.0720*	0.0738*	0.0803**	0.0803**
	(0.0383)	(0.0350)	(0.0285)	(0.0221)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	51,547	51,547	51,547	51,547
R^2	0.1222	0.1483	0.1581	0.1581
Within R^2	0.1002	0.0879	0.0885	0.0885
Bootstrap t-stat	#	#	#	3.6330
Bootstrap-t $CI(95\%)$	#	#	#	[1.466, 5.808]
Baseline Mean	5.938	5.938	5.938	5.938

NOTES: The Table is obtained from estimating equation 1. It compares logged houses/flats above-average monthly rents for treated low-income to a subgroup of the never-treated low-income households without grid connection and do not own NEES recommended appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. Rents is a self-reported time series of monthly house rents. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 7: Effect of NEES on House/Flat Monthly Rents

above-average rents	1	2	3	4
treated	50.29**	49.51**	51.64**	51.64**
	(18.50)	(18.71)	(15.44)	(11.02)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	51,547	51,547	51,547	51,547
R^2	0.1740	0.1988	0.2070	0.2070
Within R^2	0.1532	0.1471	0.1476	0.1476
Bootstrap t-stat	#	#	#	4.3785
Bootstrap-t $CI(95\%)$	#	#	#	[2.536, 6.205]
Baseline Mean	470	470	470	470

NOTES: The Table is obtained from estimating equation 1. It compares houses/flats above-average monthly rents for treated low-income to a subgroup of the never-treated low-income households without grid connection and do not own NEES recommended appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. Rents is a self-reported time series of monthly house rents. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

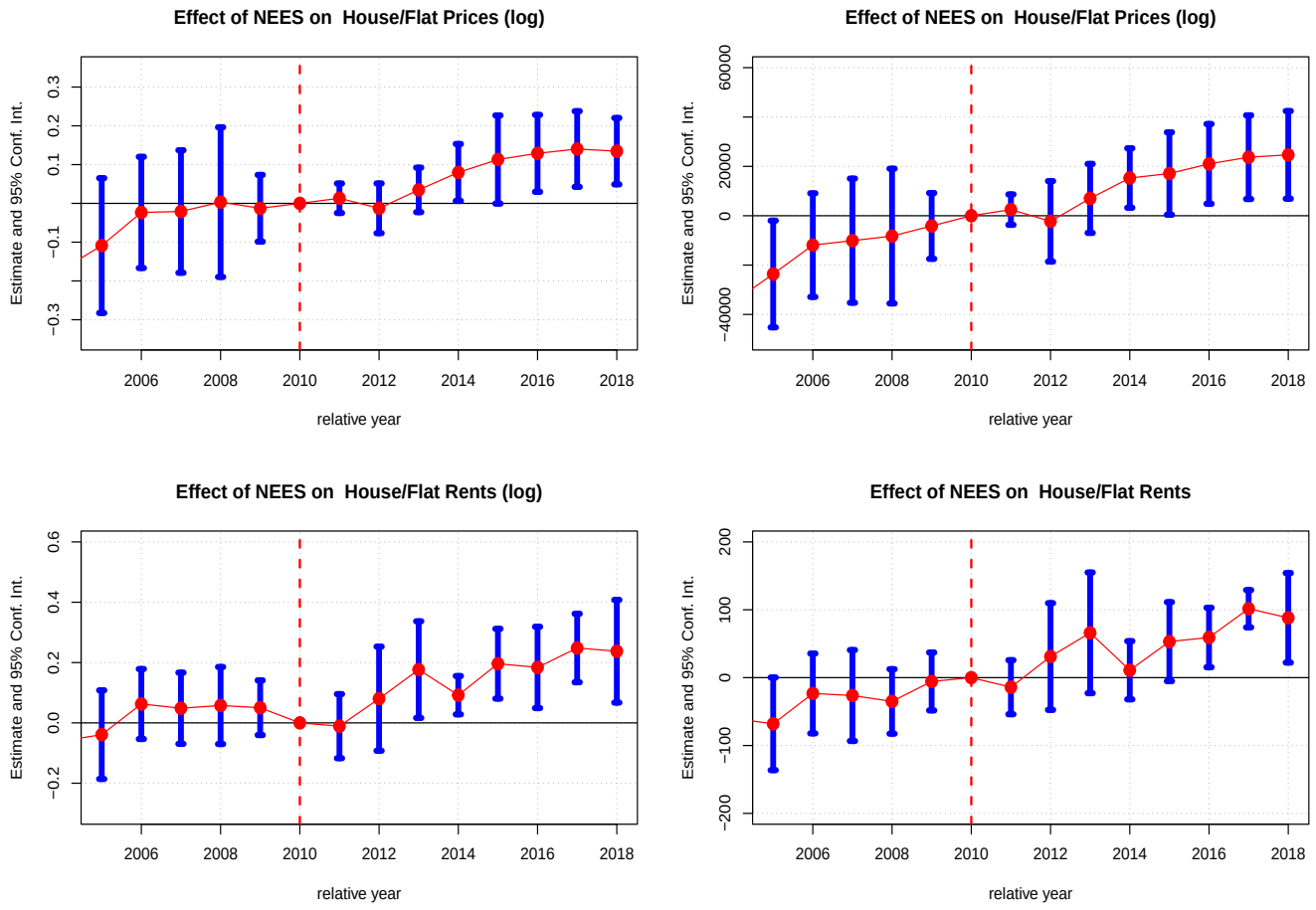


Figure 3: Event Study Plots of the Effect of NEES on House Prices and Monthly Rents

NOTES: This figure is obtained from estimating Equation 1 and compares the effect of NEES on monthly rents in treated low-income to a subgroup of the never-treated low-income households without grid connection and do not own NEES recommended appliances. The effect on property values is compared to a subgroup of the never-treated low- and high-income households without grid connection but own NEES recommended appliances. All equations are quadratic in number of rooms. Property values and rents are self-reported time series of estimated market house prices and monthly house rents. Robust standard errors are clustered at the province level.

5.4 Effects on Pollution

In this subsection, I present the results on the impact of NEES on environmental pollution outcomes. The results in Table 8 shows that NEES caused a significant negative impact on overall pollution by $5.96 ppts$. Put differently, low-income households who report pollution as an environmental problem declined following NEES. This effect persists across all models and remained significant after 1000 bootstrap replicates which increased the precision of the estimate. The result here is consistent with the engineering literature on the pollution reduction effects of energy efficiency upgrades (S. Zhang et al. 2015; 2014). This negative effect is significantly dominated in the air and water pollution, littering, and asbestos usage (see

Tables 9, 10, 11, and 13). There is limited evidence on the effect of NEES on land degradation in Table 12. Moreover, the dynamic effects are presented in Figure 4. The Figure shows an a significant decline in the overall pollution reductions beginning in the first year up to three years of post-treatment. Furthermore, the declining dynamic effect on air pollution, littering and land degradation became significant in the first year up of post-treatment and persists in the longrun. Similarly, the dynamic effect on water pollution and asbestos usage show an instantaneous declining effects which persists in the longrun. Clearly, these results significant importance of energy efficiency in tackling environmental pollution. The transmission mechanisms of the pollution reduction effects are through increases in energy efficiency adoption and increased efficiency in grid usage for domestic purposes by low-income individuals.

Table 8: Effect of NEES on Pollution

Pollution	1	2	3	4
treated	-0.0519***	-0.0529***	-0.0596***	-0.0596***
	(0.0136)	(0.0147)	(0.0116)	(0.0059)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	867,481	867,481	867,481	867,481
R^2	0.0916	0.1133	0.1177	0.1177
Within R^2	0.0774	0.0652	0.0662	0.0662
Bootstrap t-stat	#	#	#	-7.9020
Bootstrap-t $CI(95\%)$	#	#	#	[-9.770, -5.973]
Baseline Mean	0.628	0.628	0.628	0.628

NOTES: This table is got from estimating Equation 1. It compares pollution in treated low-income households to a subgroup of the never-treated low-, middle- and high-income households without grid connection but own NEES appliances.The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Pollution is a dummy that is unity if a household reported that either air, water, littering, and land degradation is an environmental problem. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 9: Effect of NEES on Air Pollution

Air pollution	1	2	3	4
treated	-0.0470**	-0.0465*	-0.0492**	-0.0492**
	(0.0203)	(0.0217)	(0.0194)	(0.0051)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	901,092	901,092	901,092	901,092
R^2	0.1473	0.1526	0.1567	0.1567
Within R^2	0.1085	0.0820	0.0832	0.0832
Bootstrap t-stat	#	#	#	-8.5214
Bootstrap-t $CI(95\%)$	#	#	#	[-10.318, -6.433]
Baseline Mean	0.471	0.471	0.471	0.471

NOTES: This table is got from estimating Equation 1. It compares air pollution in treated low-income households to a subgroup of the never-treated low- and middle-income households without grid connection and do not own any NEES appliance. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Air pollution is a dummy that is unity if a household reported that air pollution is an environmental problem. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 10: Effect of NEES on Water Pollution

Water pollution	1	2	3	4
treated	-0.0765**	-0.0728**	-0.0757**	-0.0757**
	(0.0233)	(0.0245)	(0.0248)	(0.0043)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	901,592	901,592	901,592	901,592
R^2	0.2139	0.2179	0.2245	0.2245
Within R^2	0.1357	0.1086	0.1107	0.1107
Bootstrap t-stat	#	#	#	-18.9638
Bootstrap-t $CI(95\%)$	#	#	#	[-21.280, -16.670]
Baseline Mean	0.271	0.271	0.271	0.271

NOTES: This table is got from estimating Equation 1. It compares water pollution in treated low-income households to a subgroup of the never-treated low-, middle- and high-income households without grid connection and do not own any NEES appliance. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Water pollution is a dummy that is unity if a household reported that water pollution is an environmental problem. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 11: Effect of NEES on Littering

Littering	1	2	3	4
treated	-0.0551**	-0.0557**	-0.0630***	-0.0630***
	(0.0178)	(0.0187)	(0.0166)	(0.0059)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	867,481	867,481	867,481	867,481
R^2	0.1037	0.1251	0.1301	0.1301
Within R^2	0.0879	0.0743	0.0756	0.0756
Bootstrap t-stat	#	#	#	-8.2950
Bootstrap-t $CI(95\%)$	#	#	#	[-10.151, -6.333]
Baseline Mean	0.592	0.592	0.592	0.592

NOTES: This table is got from estimating Equation 1. It compares littering in treated low-income households to a subgroup of the never-treated low- and middle-income households without grid connection but own NEES appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Littering is a dummy that is unity if a household reported that environmental littering is a problem. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 12: Effect of NEES on Land Degradation

Land Degradation	1	2	3	4
treated	-0.0043*	-0.0037	-0.0059	-0.0059
	(0.0019)	(0.0021)	(0.0035)	(0.0015)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	870,148	870,148	870,148	870,148
R^2	0.0136	0.0163	0.0187	0.0187
Within R^2	0.0132	0.0090	0.0087	0.0087
Bootstrap t-stat	#	#	#	-6.5744
Bootstrap-t $CI(95\%)$	#	#	#	[-9.437, -4.060]
Baseline Mean	0.016	0.016	0.016	0.016

NOTES: This table is got from estimating Equation 1. It compares Land degradation in treated low-income households to a subgroup of the never-treated low- and high-income households without grid connection and do not own any NEES appliance. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Land degrade is a dummy that is unity if a household reported that land degradation is an environmental problem. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 13: Effect of NEES on Asbestos Usage

Asbestos	1	2	3	4
treated	-0.0406***	-0.0389***	-0.0353***	-0.0353***
	(0.0105)	(0.0087)	(0.0079)	(0.0039)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	826,121	826,121	826,121	826,121
R^2	0.1189	0.1674	0.1708	0.1708
Within R^2	0.1142	0.0818	0.0811	0.0811
Bootstrap t-stat	#	#	#	-8.6285
Bootstrap-t $CI(95\%)$	#	#	#	[-11.045, -6.196]
Baseline Mean	0.091	0.091	0.091	0.091

NOTES: This table is got from estimating Equation 1. It compares asbestos in treated low-income households to a subgroup of the never-treated middle- and high-income households without grid connection and do not own any NEES appliance. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Asbestos is a dummy that is unity if a household reported using asbestos (a type of poor roofing material) as a roofing material. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

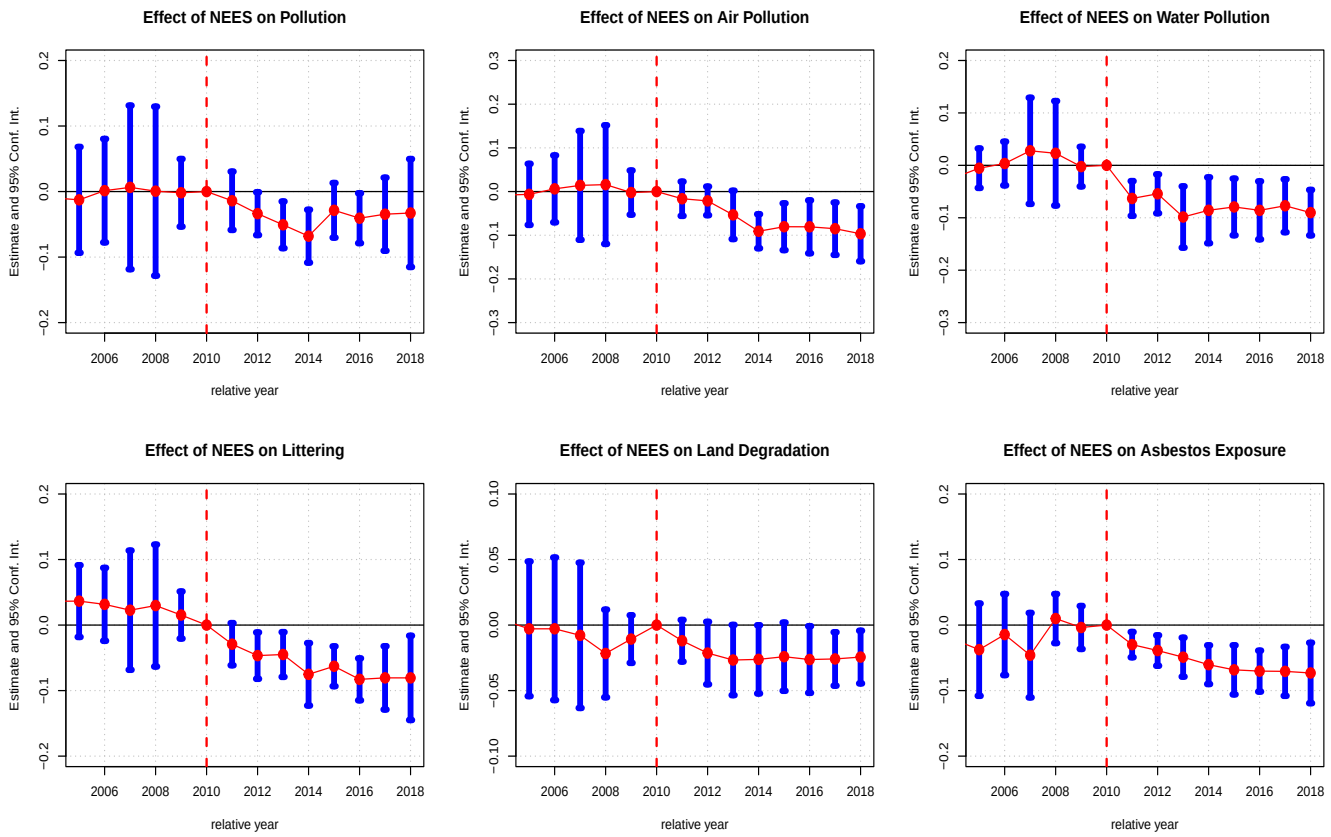


Figure 4: Event Study Plots of the Effect of NEES on Pollution Outcomes

NOTES: This figure is got from estimating Equation 1 and presents the effect of NEES on pollution outcomes—air, water, littering, noise pollution and land degradation. It compares pollution outcomes and littering for the treated low-income households to a subgroup of the never-treated low- and middle-income households without grid connection but own any NEES appliance. The effect on air and water pollution, land degradation and asbestos are compared to a subgroup of the never-treated low- and middle-income households without grid connection and do not own any NEES appliance. All equations are quadratic in number of rooms. Pollution is a dummy that is unity if they reported that either littering, air, water or noise pollution is an environmental problem. Land degradation is a dummy that is unity if households reported that land degradation is an environmental problem. Asbestos is a dummy that is unity if households reported using asbestos material as a roofing material. Robust standard errors are clustered at the province level.

5.5 Effects on Non-chronic Morbidity

This subsection presents evidence on the impact of NEES on non-chronic morbidity for low-income South Africans. Table 14 shows that an increase in energy efficiency adoption caused a significant decline in non-chronic morbidity, by $5.32ppts$ That is, NEES caused a decrease in the number of low-income individuals who report of suffering from at least one non-chronic morbidity in terms of the respiratory infections, diarrhoea, severe tuberculosis, and mental illness. Several health literature have corroborative evidence on public health gains of environmental improvements (Kearns et al. 2023; Singh et al. 2018; Hertz-Picciotto et al. 2007; McDermott 1961). The results further show that except for Table 15, Tables 16, and 18 show that these effects are dominated in diarrhoea, severe tuberculosis and mental illnesses and robust after

1000 bootstrap replicates. The dynamic results in Figure 6 shows an instantaneous effect of NEES on non-chronic morbidity and persist up to five year after treatment. Similar effects are observed for low-income individuals suffering from severe tuberculosis. The declining effect on respiratory infection and diarrhoea became significant from the second year and persists up to five years after treatment. Additionally, these effects are transmitted through pollution reductions due to NEES.

Table 14: Effect of NEES on Non-chronic Morbidity

Non-chronic Morbidity	1	2	3	4
treated	-0.0532***	-0.0496***	-0.0550***	-0.0550***
	(0.0119)	(0.0135)	(0.0125)	(0.0037)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	394,817	394,817	394,817	394,817
R^2	0.2680	0.2712	0.2738	0.2738
Within R^2	0.1904	0.1422	0.1415	0.1415
Bootstrap t-stat	#	#	#	-14.9601
Bootstrap-t $CI(95\%)$	#	#	#	[-17.220, -12.440]
Baseline Mean	0.346	0.346	0.346	0.346

NOTES: This table is got from estimating Equation 1. It compares non-chronic morbidity among individuals in treated low-income households to the never-treated low- and middle-income households. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Non-chronic morbidity is a dummy that is unity if an individual suffers from either flu/respiratory infections, diarrhoea, severe TBC, and mental illness or depression. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

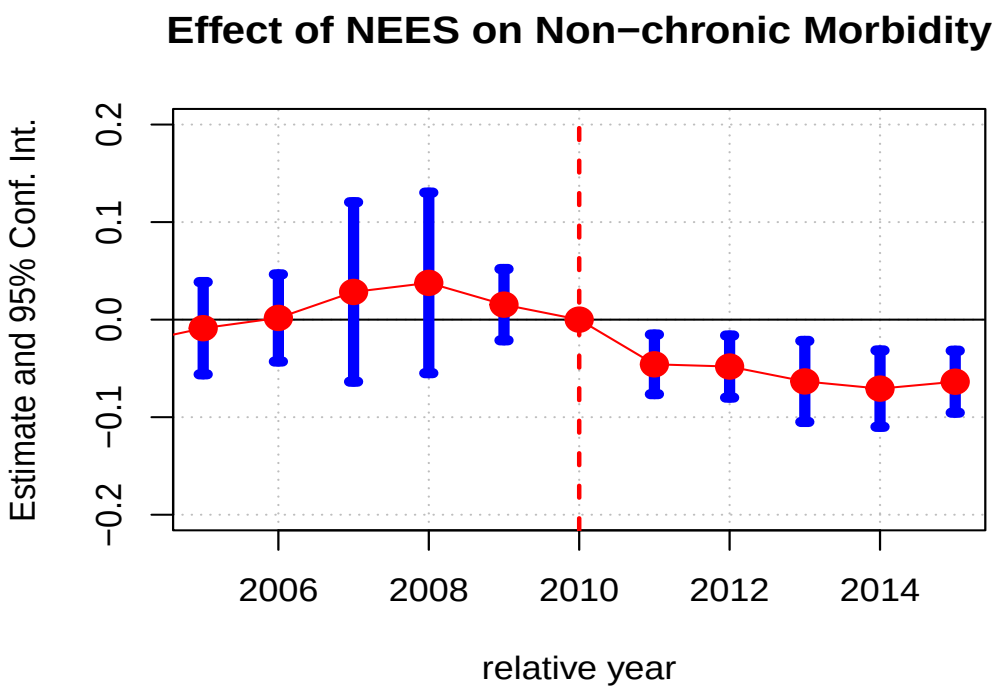


Figure 5: Event Study Plots of the Effect of NEES on Non-chronic Morbidity

NOTES: This figure is obtained from estimating Equation 1 and compares the effect of NEES on non-chronic morbidity in treated low-income households to the never-treated low- and middle-income households. Non-chronic morbidity is a dummy that is unity if an individual suffers from either flu/respiratory infections, diarrhoea, severe tuberculosis, alcohol-related illness, mental illness and any sexual transmitted diseases (STDs). All equations are quadratic in number of rooms. Robust standard errors are clustered at the village level.

Table 15: Effect of NEES on Respiratory Infections

Respiratory Infections	1	2	3	4
treated	-0.0072	-0.0071	-0.0066	-0.0066
	(0.0039)	(0.0040)	(0.0044)	(0.0017)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	335,485	335,485	335,485	335,485
R^2	0.0137	0.0141	0.0168	0.0168
Within R^2	0.0065	0.0047	0.0046	0.0046
Bootstrap t-stat	#	#	#	-3.9272
Bootstrap-t $CI(95\%)$	#	#	#	[-6.954, -0.799]
Baseline Mean	0.019	0.019	0.019	0.019

NOTES: This table is got from estimating Equation 1. It compares respiratory infection among individuals in treated low-income households to a subgroup of the never-treated low-, middle and high-income households without grid connection but own NEES recommended appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Flu/respiratory infection is a dummy that is unity if an individual suffers from a flu/respiratory disease, and zero otherwise. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 16: Effect of NEES on Diarrhoea

Diarrhoea	1	2	3	4
treated	-0.0022*	-0.0023*	-0.0022*	-0.0022*
	(0.0011)	(0.0011)	(0.0010)	(0.0000)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	376,865	376,865	376,865	376,865
R^2	0.0029	0.0031	0.0041	0.0041
Within R^2	0.0004	0.0004	0.0004	0.0004
Bootstrap t-stat	#	#	#	-3.5815
Bootstrap-t $CI(95\%)$	#	#	#	[-5.875, -1.173]
Baseline Mean	0.009	0.009	0.009	0.009

NOTES: This table is got from estimating Equation 1. It compares diarrhoea among individuals in treated low-income households to a subgroup of the never-treated low-, middle- and high-income households without grid connection and do not own any NEES recommended appliance. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Diarrhoea is a dummy that is unity if an individual suffers from a diarrhoea, and zero otherwise. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 17: Effect of NEES on Severe TBC

Tuberculosis	1	2	3	4
treated	-0.0549***	-0.0508**	-0.0563***	-0.0563***
	(0.0137)	(0.0156)	(0.0146)	(0.0037)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	394,937	394,937	394,937	394,937
R^2	0.2724	0.2758	0.2784	0.2784
Within R^2	0.1941	0.1451	0.1444	0.1444
Bootstrap t-stat	#	#	#	-15.3475
Bootstrap-t $CI(95\%)$	#	#	#	[-17.650, -12.800]
Baseline Mean	0.335	0.335	0.335	0.335

NOTES: This table is got from estimating Equation 1. It compares severe TBC among individuals in treated low-income households to the never-treated low-, middle- and high-income households. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Severe TBC is a dummy that is unity if an individual suffers from severe tuberculosis, and zero otherwise. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 18: Effect of NEES on Depression

Depression	1	2	3	4
treated	-0.0015*	-0.0016**	-0.0012*	-0.0012*
	(0.0007)	(0.0007)	(0.0005)	(0.0000)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	376,865	376,865	376,865	376,865
R^2	0.0054	0.0058	0.0071	0.0071
Within R^2	0.0011	0.0010	0.0010	0.0010
Bootstrap t-stat	#	#	#	-2.8039
Bootstrap-t $CI(95\%)$	#	#	#	[-5.662, -0.127]
Baseline Mean	0.006	0.006	0.006	0.006

NOTES: This table is got from estimating Equation 1. It compares depressions among individuals in treated low-income households to a subgroup of the never-treated low-, middle- and high-income households without grid connection and do not own any NEES recommended appliance. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Depression is a dummy that is unity if an individual suffers from any form of mental illness or depression. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

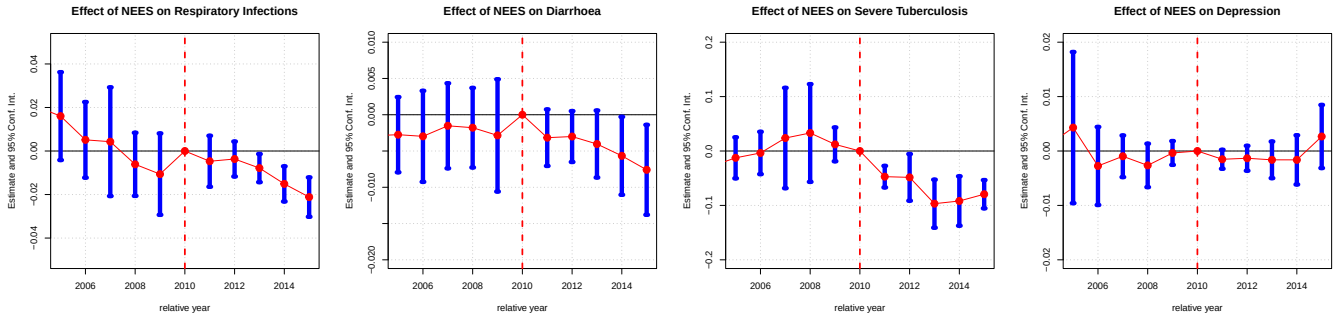


Figure 6: Event Study Plots of the Effect of NEES on Types of Non-chronic Morbidity

NOTES: This figure is obtained from estimating Equation 1 and compares the effect of NEES on types of non-chronic morbidity including diarrhoea and mental illness in treated low-income households to a subgroup of the never-treated low-, middle- and high-income households without grid connection and do not own NEES recommended appliances. The effect of flu/respiratory infections is compared to a subgroup of the never-treated low-, middle- and high-income households without grid connection and but own NEES recommended appliances, where the effect on severe tuberculosis is compared to the never-treated low-, middle- and high-income households. All equations are quadratic in number of rooms. Non-chronic morbidity is a dummy that is unity if an individual suffers from either flu/respiratory infections, diarrhoea, severe tuberculosis, alcohol-related illness, mental illness and STDs. Robust standard errors are clustered at the province level.

6 Robustness Checks

I conduct several robustness checks on the results ranging from placebo exercises, alternative clusterinf of the standard errors, investigating potential issues of selection into treatment, pre-trends testing, and alternative model specifications and experiment designs. In what follows, I discuss these robustness checks in more detail.

6.1 Falsification Tests

$$C_{j,h,v,p,t} = \beta_1 Treated^{e}_{h,v,p,t} + \beta_2 Grid_{h,v,p,t} + \beta_3 DU_{h,v,p,t} + \beta_4 NEESAPP_{h,v,p,t} + \beta_5 LincH_{h,v,p,t} + \phi P_{j,h,v,p,t} + \omega H_{h,v,p,t} + \lambda_t + \delta_p + \theta_{p,t} + \varepsilon_{j,h,v,p,t}, \quad (2)$$

To test the internal consistency of the presented causal results, I estimate equation 2 to evidence the effect of NEES on house prices and monthly rents attributable to the vector, $C_{j,h,v,p,t}$—domestic coal usage, prices of informal dwellings, below-average household monthly rents, pollution attributable to noise from social or business activities, busy traffic or from the local market areas in urban centres, and alcoholism attributable to individual drinking habits, and STDs attributable to individual sexual experiences. All RHS vectors are as defined in Section 5. Prices of informal dwellings are expected to be uncorrelated with NEES since there is less likelihood that these dwellers in this type of housing would adopt the NEES programme because they are not grid-connected, the dwellers are unlikely to be able to afford the cost of NEES appliances, and most importantly, the conditions of these dwellings and dwellings may not support energy efficiency upgrades. Concurrently, low-income renters whose monthly rents are below the low-income group's average of $R470$ are expected to be uncorrelated with NEES because such rental housing are located in areas not covered by the grid. Also, the socioeconomic conditions of these renters may not support energy efficiency improvements due to affordability issues. Similarly, urban noise pollution from social activities, busy traffic or from local market areas, as well as individuals drinking habits and STDs from indiscriminate sexual experiences would most likely be uncorrelated with NEES. Noteworthy, a weak

correlation in these exercises does not necessarily prove the causal impact of NEES on the main outcomes. However, a significant impact would substantially reduce confidence in the results given that there is no clear mechanism linking NEES to the prices of informal dwellings, below-average monthly rents, urban noise pollution, alcoholism and STDs in South Africa. After controlling for the fixed effects and provincial linear trends, the results in Tables 19, 20, 24, 25 and 26 generally show no correlations between NEES and the aforementioned outcomes. These results rule out any suspicions of spurious relations in the presented causal estimates in Tables 5, 7, 8 and 14, thus, raising the credibility and confidence that the recovered NEES effects on these outcomes are indeed causal.

Table 19: Effect of NEES on Domestic Dung Usage

dung usage	1	2	3	4
treated	-0.0003	-0.0003	0.0003	0.0003
	(0.0008)	(0.0008)	(0.0009)	(0.0006)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province FEs	No	No	Yes	Yes
Observations	839,541	839,541	839,541	839,541
R^2	0.0048	0.0058	0.0065	0.0065
Within R^2	0.0046	0.0035	0.0035	0.0035
Bootstrap t-stat	#	#	#	-0.4100
Bootstrap-t $CI(95\%)$	#	#	#	[-1.6754, 0.8252]
Baseline Mean	0.003	0.003	0.003	0.003

NOTES: The Table is obtained from estimating equation 2. It compares domestic animal dung usage of the treated low-income households to a subgroup of the never-treated low-, middle- and high-income households without grid connection but own NEES recommended appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. Dung usage is a dummy that is unity if a household uses animal dung energy source for lighting, cooking and heating purposes, and zero otherwise. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 20: Effect of NEES on Prices of Informal Dwellings (log)

informal prices (log)	1	2	3	4
treated	0.0101	0.0113	-0.0123	-0.0123
	(0.0308)	(0.0306)	(0.0226)	(0.0096)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	38,561	38,561	38,561	38,561
R^2	0.0329	0.0403	0.0570	0.0570
Within R^2	0.0296	0.0231	0.0222	0.0222
Bootstrap t-stat	#	#	#	-1.2819
Bootstrap-t $CI(95\%)$	#	#	#	[-3.213, 0.531]
Baseline Mean	11.475	11.475	11.475	11.475

NOTES: The Table is obtained from estimating equation 1. It compares logged informal property values for treated low-income to a subgroup of the never-treated low- and high-income households without grid connection but own NEES recommended appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. Trad/Informal prices is a self-reported time series of estimated market house prices for traditional/informal dwellings. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 21: Effect of NEES on Prices of Informal Dwellings

informal prices	1	2	3	4
treated	1,773.9	1,935.1	-138.6	-138.6
	(3,173.0)	(3,189.3)	(1,905.1)	(1177.6)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	38,561	38,561	38,561	38,561
R^2	0.0279	0.0327	0.0503	0.0503
Within R^2	0.0257	0.0203	0.0187	0.0187
Bootstrap t-stat	#	#	#	-0.1177
Bootstrap-t $CI(95\%)$	#	#	#	[-1.4841, 1.0675]
Baseline Mean	149488	149488	149488	149488

NOTES: The Table is obtained from estimating equation 1. It compares informal property values for treated low-income to a subgroup of the never-treated low- and high-income households without grid connection but own NEES recommended appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. Trad/Informal prices is a self-reported time series of estimated market house prices for traditional/informal dwellings. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 22: Effect of NEES on Below-Average Rents (log)

below-mean rents	1	2	3	4
treated	-0.0158	-0.0152	-0.0186	-0.0186
	(0.0276)	(0.0278)	(0.0277)	(0.0168)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	29,295	29,295	29,295	29,295
R^2	0.0017	0.0017	0.0055	0.0055
Within R^2	0.0008	0.0008	0.0008	0.0008
Bootstrap t-stat	#	#	#	-1.1013
Bootstrap-t $CI(95\%)$	#	#	#	[-3.206, 1.419]
Baseline Mean	5.938	5.938	5.938	5.938

NOTES: The Table is obtained from estimating equation 1. It compares less than average logged monthly rents for treated low-income to a subgroup of the never-treated low- and high-income households without grid connection and do not own any NEES appliance. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. Traditional rents is a self-reported time series of monthly house rents for traditional dwellings. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 23: Effect of NEES on Below-Average Rents

below-mean rents	1	2	3	4
treated	-3.672	-3.504	-3.861	-3.861
	(5.626)	(5.631)	(5.506)	(3.5846)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	29,295	29,295	29,295	29,295
R^2	0.0016	0.0017	0.0056	0.0056
Within R^2	0.0008	0.0008	0.0008	0.0008
Bootstrap t-stat	#	#	#	-1.0772
Bootstrap-t $CI(95\%)$	#	#	#	[-3.278, 1.489]
Baseline Mean	470	470	470	470

NOTES: The Table is obtained from estimating equation 1. It compares less than average monthly rents for treated low-income to a subgroup of the never-treated low- and high-income households without grid connection and do not own any NEES appliance. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. Traditional rents is a self-reported time series of monthly house rents for traditional dwellings. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 24: Effect of NEES on Urban Noise Pollution

noise pollution	1	2	3	4
treated	-0.0144	-0.0158	-0.0211	-0.0211
	(0.0265)	(0.0273)	(0.0250)	(0.0054)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	705,003	705,003	705,003	705,003
R^2	0.0300	0.0408	0.0447	0.0447
Within R^2	0.0262	0.0306	0.0305	0.0305
Bootstrap t-stat	#	#	#	-3.8863
Bootstrap-t $CI(95\%)$	#	#	#	[-6.630, -0.943]
Baseline Mean	0.161	0.161	0.161	0.161

NOTES: This table is got from estimating Equation 1 and compares urban noise pollution in treated low-income households to a subgroup of the never-treated low-, middle- and high-income households without grid connection but own NEES recommended appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender-male vs female, marital status-married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, and a type of house dummy. Noise pollution is a dummy that is unity for households if they reported that noise pollution is an environmental problem. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 25: Effect of NEES on Alcohol Abuses

alcoholism	1	2	3	4
treated	-6.82e-5	-7.77e-5	-0.0001	-0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	375,404	375,404	375,404	375,404
R^2	0.0008	0.0008	0.0021	0.0021
Within R^2	0.0002	0.0001	0.0002	0.0021
Bootstrap t-stat	#	#	#	-0.7377
Bootstrap-t $CI(95\%)$	#	#	#	[-2.7018, 0.9345]
Baseline Mean	0.001	0.001	0.001	0.001

NOTES: This table is got from estimating Equation 1 and compares alcohol illness in treated low-income households to the never-treated low- and high-income households. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender-male vs female, marital status-married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, and a type of house dummy. Alcoholism is a dummy that is unity if a low-income individual is an alcoholic or abuses alcohol. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 26: Effect of NEES on STDs

std	1	2	3	4
treated	-0.0005	-0.0005	-0.0005	-0.0005
	(0.0003)	(0.0003)	(0.0003)	(0.0002)
controls	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes
province FEs	No	Yes	Yes	Yes
year x province LTs	No	No	Yes	Yes
Observations	335,485	335,485	335,485	335,485
R^2	0.0007	0.0007	0.0018	0.0018
Within R^2	0.0002	0.0002	0.0002	0.0002
Bootstrap t-stat	#	#	#	-2.0796
Bootstrap-t $CI(95\%)$	#	#	#	[-6.591, 0.885]
Baseline Mean	0.000	0.000	0.000	0.000

NOTES: This table is got from estimating Equation 1 and compares STDs in treated low-income households to a subgroup of the never-treated low-, middle- and high-income households without grid connection but own NEES recommended appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender-male vs female, marital status-married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, and a type of house dummy. STD is a dummy that is unity if an individual suffers from any form of STDs. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

6.2 Investigating Potential Selection Issues

$$Treated^{e}_{h,v,p,t} = \beta_1 Grid_{h,v,p,t} + \beta_2 DU_{h,v,p,t} + \beta_3 NEESAPP_{h,v,p,t} + \beta_4 LincH_{h,v,p,t} + \phi P_{j,h,v,p,t} + \omega H_{h,v,p,t} + \lambda_t + \delta_p + \theta_{p,t} + \varepsilon_{j,h,v,p,t}, \quad (3)$$

Another concern in quasi-experimental designs is the issue of potential selection into treatment between the treated and never-treated groups given the differences in their observable compositional characteristics. I investigate this possible selection into treatment in equation 3, where $\zeta R_{j,h,v,p,t}$ are additional channels through which treatment selection issues can occur such as homeownership, business ownership, household

income sources, house prices, pollution, and, paid and unpaid employment. All other RHS vector and fixed effects are as defined in the previous sections. The result in Table 27 shows that the treatment may have been selective on some observable household characteristics such that the treatment may be driven by some pre-treatment covariates. For example, there may be a negative selection on low-income households with unpaid employment or those reporting that water pollution directly poses an environmental problem, or those that have water piped into their dwellings. This means that these low-income households are less likely to be treated and would under-estimate the causal effect on the outcomes if not controlled for in the regression model. On the other hand, there is a positive selection on the grid connection, low-income households, race, homeowners, business owners and income sources of all households. Thus, low-income households characterised by these observables may have been selected into treatment and if not controlled for, would over-estimate the effect on the outcomes. Based on these results, I re-estimate equation 1 separately adding the significant variables in Table 27 that are not already controlled for to the regression model. Importantly, the results show that the inclusion of these significant covariates have no substantial impact on the outcomes in Tables of Sub-sections 6.2.1, 6.2.2, 6.2.3, and 6.2.4 further raising confidence in the recovered causal impact of NEES on the outcomes.

Table 27: Checks for Possible Selection on Observables

Dependent Var	treated
grid	-0.0002 (0.0059)
domestic electricity usage	0.9279*** (0.0081)
ownership of NEES appliances	-0.0001 (0.0060)
low-income households	0.0331*** (0.0052)
age	-6.16e-6 (2.39e-5)
male	0.0034*** (0.0005)
married	0.0009 (0.0015)
metro	0.0002 (0.0018)
rural	0.0067 (0.0050)
black	0.0055*** (0.0014)
white	0.0022 (0.0045)
house proximity to water source	0.0037 (0.0033)
house proximity to toilet	0.0075 (0.0080)
house proximity to school	0.0015 (0.0008)
piped water into dwellings	-0.0029* (0.0013)
traditional dwelling	0.0025 (0.0026)
land access	0.0048 (0.0072)
water pollution	-0.0064** (0.0023)
number of rooms	5.74e-6 (4.48e-5)
number of rooms squared	0.0003 (0.0008)
homeownership	0.0029* (0.0014)
business ownership	0.0038* (0.0019)
house price (log)	0.0042** (0.0017)
household expenditure	-0.0015 (0.0009)
all household income sources	0.0014* (0.0006)
paid employment	0.0011 (0.0009)
unpaid employment	-0.0056** (0.0019)
house subsidy beneficiaries	-0.0001 (0.0010)
year, province, province LTs	Yes
Observations	816,658
R^2	0.9403
Within R^2	0.9253

NOTES: This table compares treated low-income vs. never-treated low-, middle- and high-income households. Treated is a dummy that is unity for NEES eligible low-income households treated between 2011 and 2012, otherwise never-treated low-, middle- and high-income households. ***, **, and * denote less than 0.1%, 5% and 10% significance levels, respectively.

6.2.1 Selection Issues on Programme Adoption and Grid Usage

Table 28: Selection Checks on the Effect of NEES on Programme Adoption

nees adoption	1	2	3	4	5	6	7	8	9
treated	0.0182*	0.0186*	0.0185*	0.0185*	0.0163	0.0161	0.0230***	0.0151*	0.0151*
	(0.0096)	(0.0091)	(0.0091)	(0.0091)	(0.0089)	(0.0089)	(0.0066)	(0.0079)	(0.0010)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
homeownership	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
paid employment	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
unpaid employment	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
business ownership	No	No	No	No	Yes	Yes	Yes	Yes	Yes
all household income sources	No	No	No	No	No	Yes	Yes	Yes	Yes
house subsidy beneficiaries	No	No	No	No	No	No	Yes	Yes	Yes
house price (log)	No	No	No	No	No	No	No	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	901,592	901,592	901,592	901,592	901,592	901,592	901,592	758,960	758,960
R^2	0.0937	0.1005	0.1006	0.1006	0.1498	0.1500	0.9437	0.9407	0.9407
Within R^2	0.0652	0.0722	0.0723	0.0723	0.1230	0.1233	0.9419	0.9384	0.9384
Bootstrap t-stat	#	#	#	#	#	#	#	#	15.2201
Bootstrap-t $CI(95\%)$	#	#	#	#	#	#	#	#	[10.480, 19.120]

NOTES: The Table is obtained from estimating equation 1. It compares energy efficiency adoption between the treated low-income and the never-treated low- middle- and high-income households. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. NEES adoption is a dummy that is unity if a household is connected to the grid and own any NEES recommended appliance, deliberately reduced their energy consumption or exhibit energy efficiency behaviours, and zero otherwise. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 29: Selection Checks on the Effect of NEES on Domestic Grid Usage

grid usage	1	2	3	4	5	6	7	8	9
treated	0.0091*	0.0080	0.0078	0.0078	0.0062	0.0074	0.0112**	0.0148**	0.0148**
	(0.0046)	(0.0045)	(0.0045)	(0.0045)	(0.0043)	(0.0044)	(0.0037)	(0.0056)	(0.0027)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
homeownership	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
paid employment	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
unpaid employment	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
business ownership	No	No	No	No	Yes	Yes	Yes	Yes	Yes
all household income sources	No	No	No	No	No	Yes	Yes	Yes	Yes
house subsidy beneficiaries	No	No	No	No	No	No	Yes	Yes	Yes
house price (log)	No	No	No	No	No	No	No	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	871,485	871,485	871,485	871,485	871,485	871,485	871,485	727,790	727,790
R^2	0.0741	0.0767	0.0767	0.0767	0.1894	0.1975	0.5293	0.5350	0.5350
Within R^2	0.0529	0.0557	0.0557	0.0557	0.1710	0.1792	0.5186	0.5247	0.5247
Bootstrap t-stat	#	#	#	#	#	#	#	#	5.5696
Bootstrap-t $CI(95\%)$	#	#	#	#	#	#	#	#	[3.445, 7.438]

NOTES: The Table is obtained from estimating equation 1. It compares domestic grid usage of the treated low-income to the never-treated middle- and high-income households. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. Domestic grid usage is a dummy that is unity if a grid connected household uses the grid electricity supply for domestic purposes such as heating, cooking and lighting purposes, and zero otherwise. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

6.2.2 Selection Issues on House Prices and Rents

Table 30: Selection Checks on the Effect of NEES on House/Flat Prices

house price	1	2	3	4	5	6	7	8
treated	6,619.1*	6,608.0*	6,620.5*	6,613.3*	6,663.4*	6,589.2*	6,372.3*	6,372.3*
	(2,967.8)	(2,954.7)	(2,890.9)	(2,891.6)	(2,913.2)	(2,867.0)	(3,395.9)	(2403.7)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
homeownership	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
paid employment	No	No	Yes	Yes	Yes	Yes	Yes	Yes
unpaid employment	No	No	No	Yes	Yes	Yes	Yes	Yes
business ownership	No	No	No	No	Yes	Yes	Yes	Yes
all household income sources	No	No	No	No	No	Yes	Yes	Yes
house subsidy beneficiaries	No	No	No	No	No	No	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	559,124	559,124	559,124	559,124	559,124	559,124	559,124	559,124
R^2	0.3387	0.3387	0.3394	0.3394	0.3401	0.3405	0.3575	0.3575
Within R^2	0.2767	0.2768	0.2775	0.2775	0.2783	0.2788	0.2973	0.2973
Bootstrap t-stat	#	#	#	#	#	#	#	2.6511
Bootstrap-t $CI(95\%)$	#	#	#	#	#	#	#	[0.519, 4.764]

NOTES: The Table is obtained from estimating equation 1. It compares houses/flats property values for treated low-income to a subgroup of the never-treated low- and high-income households without grid connection but own NEES recommended appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. House prices is a self-reported time series of estimated market house prices. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 31: Selection Checks on the Effect of NEES on House/Flat Prices (log)

house price	1	2	3	4	5	6	7	8
treated	0.0332*	0.0334*	0.0334*	0.0334*	0.0336*	0.0333*	0.0323	0.0323
	(0.0157)	(0.0155)	(0.0154)	(0.0155)	(0.0155)	(0.0152)	(0.0176)	(0.0123)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
homeownership	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
paid employment	No	No	Yes	Yes	Yes	Yes	Yes	Yes
unpaid employment	No	No	No	Yes	Yes	Yes	Yes	Yes
business ownership	No	No	No	No	Yes	Yes	Yes	Yes
all household income sources	No	No	No	No	No	Yes	Yes	Yes
house subsidy beneficiaries	No	No	No	No	No	No	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	559,124	559,124	559,124	559,124	559,124	559,124	559,124	559,124
R^2	0.3478	0.3480	0.3483	0.3483	0.3488	0.3491	0.3631	0.3631
Within R^2	0.2839	0.2840	0.2844	0.2844	0.2850	0.2853	0.3006	0.3006
Bootstrap t-stat	#	#	#	#	#	#	#	2.6197
Bootstrap-t $CI(95\%)$	#	#	#	#	#	#	#	[0.532, 4.719]

NOTES: The Table is obtained from estimating equation 1. It compares logged houses/flats property values for treated low-income to a subgroup of the never-treated low- and high-income households without grid connection but own NEES recommended appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. House prices is a self-reported time series of estimated market house prices. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 32: Selection Checks on the Effect of NEES on Above-Average House/Flat Rents

rents	1	2	3	4	5	6	7	8
treated	51.64**	53.67***	51.64***	51.65***	51.66***	53.03***	48.23***	48.23***
	(15.44)	(14.62)	(14.22)	(14.22)	(14.33)	(14.53)	(17.97)	(11.02)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
homeownership	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
paid employment	No	No	Yes	Yes	Yes	Yes	Yes	Yes
unpaid employment	No	No	No	Yes	Yes	Yes	Yes	Yes
business ownership	No	No	No	No	Yes	Yes	Yes	Yes
all household income sources	No	No	No	No	No	No	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	51,547	51,547	51,547	51,547	51,547	51,547	51,547	51,547
R^2	0.2070	0.2106	0.2113	0.2113	0.2117	0.2135	0.2220	0.2220
Within R^2	0.1476	0.1514	0.1522	0.1522	0.1526	0.1546	0.1637	0.1637
Bootstrap t-stat	#	#	#	#	#	#	#	4.3785
Bootstrap-t $CI(95\%)$	#	#	#	#	#	#	#	[2.536, 6.205]

NOTES: The Table is obtained from estimating equation 1. It compares houses/flats above-average monthly rents for treated low-income to a subgroup of the never-treated low- and high-income households without grid connection and do not own NEES recommended appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. Rents is a self-reported time series of monthly house rents. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 33: Selection Checks on the Effect of NEES on Above-Average House/Flat Rents (log)

rents	1	2	3	4	5	6	7	8
treated	0.0803**	0.0841**	0.0811**	0.0811**	0.0812**	0.0837**	0.0749***	0.0749***
	(0.0285)	(0.0267)	(0.0267)	(0.0267)	(0.0268)	(0.0266)	(0.0300)	(0.0219)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
homeownership	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
paid employment	No	No	Yes	Yes	Yes	Yes	Yes	Yes
unpaid employment	No	No	No	Yes	Yes	Yes	Yes	Yes
business ownership	No	No	No	No	Yes	Yes	Yes	Yes
all household income sources	No	No	No	No	No	Yes	Yes	Yes
house subsidy beneficiaries	No	No	No	No	No	No	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	51,547	51,547	51,547	51,547	51,547	51,547	51,547	51,547
R^2	0.1581	0.1617	0.1621	0.1621	0.1626	0.1643	0.1722	0.1722
Within R^2	0.0885	0.0924	0.0929	0.0929	0.0934	0.0953	0.1038	0.1038
Bootstrap t-stat	#	#	#	#	#	#	#	3.4257
Bootstrap-t $CI(95\%)$	#	#	#	#	#	#	#	[1.261, 5.560]

NOTES: The Table is obtained from estimating equation 1. It compares logged houses/flats above-average monthly rents for treated low-income to a subgroup of the never-treated low- and high-income households without grid connection and do not own NEES recommended appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. Rents is a self-reported time series of monthly house rents. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

6.2.3 Selection Issues on Pollution Outcomes

Table 34: Selection Checks on the Effect of NEES on Pollution

pollution	1	2	3	4	5	6	7	8	9
treated	-0.0596***	-0.0477***	-0.0476***	-0.0475***	-0.0470***	-0.0457***	-0.0454***	-0.0463***	-0.0463***
	(0.0116)	(0.0111)	(0.0120)	(0.0120)	(0.0118)	(0.0115)	(0.0114)	(0.0103)	(0.0059)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
homeownership	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
paid employment	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
unpaid employment	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
business ownership	No	No	No	No	Yes	Yes	Yes	Yes	Yes
all household income sources	No	No	No	No	No	Yes	Yes	Yes	Yes
house subsidy beneficiaries	No	No	No	No	No	No	Yes	Yes	Yes
house price (log)	No	No	No	No	No	No	No	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	867,481	867,481	867,481	867,481	867,481	867,481	867,481	724,109	724,109
R^2	0.1177	0.1495	0.1518	0.1519	0.1527	0.1577	0.1579	0.1375	0.1375
Within R^2	0.0662	0.0999	0.1023	0.1024	0.1032	0.1085	0.1087	0.0914	0.0914
Bootstrap t-stat	#	#	#	#	#	#	#	#	-7.9020
Bootstrap-t $CI(95\%)$	#	#	#	#	#	#	#	#	[-9.770, -5.973]

NOTES: This table is got from estimating Equation 1. It compares pollution in treated low-income households to a subgroup of the never-treated low-, middle- and high-income households without grid connection but own NEES appliances.The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 35: Selection Checks on the Effect of NEES on Air Pollution

air pollution	1	2	3	4	5	6	7	8	9
treated	-0.0492**	-0.0497**	-0.0511**	-0.0510**	-0.0504**	-0.0502**	-0.0504**	-0.0435**	-0.0435**
	(0.0194)	(0.0167)	(0.0165)	(0.0165)	(0.0165)	(0.0164)	(0.0162)	(0.0166)	(0.0051)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
homeownership	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
paid employment	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
unpaid employment	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
business ownership	No	No	No	No	Yes	Yes	Yes	Yes	Yes
all household income sources	No	No	No	No	No	Yes	Yes	Yes	Yes
house subsidy beneficiaries	No	No	No	No	No	No	Yes	Yes	Yes
house price (log)	No	No	No	No	No	No	No	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	901,092	901,092	901,092	901,092	901,092	901,092	901,092	758,534	758,534
R^2	0.1567	0.2054	0.2106	0.2106	0.2118	0.2180	0.2188	0.1880	0.1880
Within R^2	0.1567	0.1361	0.1417	0.1418	0.1431	0.1499	0.1507	0.1292	0.1299
Bootstrap t-stat	#	#	#	#	#	#	#	#	-8.5214
Bootstrap-t $CI(95\%)$	#	#	#	#	#	#	#	#	[-10.318, -6.433]

NOTES: This table is got from estimating Equation 1. It compares air pollution in treated low-income households to a subgroup of the never-treated low- and middle-income households without grid connection and do not own any NEES appliance. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Air pollution is a dummy that is unity if a household reported that air pollution is an environmental problem. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 36: Selection Checks on the Effect of NEES on Water Pollution

water pollution	1	2	3	4	5	6	7	8	9
treated	-0.0757**	-0.0757**	-0.0770***	-0.0770***	-0.0763***	-0.0762***	-0.0762***	-0.0822**	-0.0822**
	(0.0248)	(0.0233)	(0.0223)	(0.0223)	(0.0223)	(0.0218)	(0.0217)	(0.0272)	(0.0043)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
homeownership	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
paid employment	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
unpaid employment	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
business ownership	No	No	No	No	Yes	Yes	Yes	Yes	Yes
all household income sources	No	No	No	No	No	Yes	Yes	Yes	Yes
house subsidy beneficiaries	No	No	No	No	No	No	Yes	Yes	Yes
house price (log)	No	No	No	No	No	No	No	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	901,592	901,592	901,592	901,592	901,592	901,592	901,592	758,960	758,960
R^2	0.2245	0.2390	0.2516	0.2516	0.2532	0.2740	0.2740	0.2550	0.2550
Within R^2	0.1107	0.1273	0.1419	0.1419	0.1437	0.1675	0.1675	0.1654	0.1654
Bootstrap t-stat	#	#	#	#	#	#	#	#	-18.9638
Bootstrap-t $CI(95\%)$	#	#	#	#	#	#	#	#	[-21.280, -16.670]

NOTES: This table is got from estimating Equation 1. It compares water pollution in treated low-income households to a subgroup of the never-treated low-, middle- and high-income households without grid connection and do not own any NEES appliance. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Water pollution is a dummy that is unity if a household reported that water pollution is an environmental problem. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 37: Selection Checks on the Effect of NEES on Littering

littering	1	2	3	4	5	6	7	8	9
treated	-0.0630***	-0.0505**	-0.0504**	-0.0503**	-0.0497**	-0.0484**	-0.0480**	-0.0490**	-0.0490**
	(0.0166)	(0.0163)	(0.0172)	(0.0172)	(0.0170)	(0.0167)	(0.0165)	(0.0147)	(0.0059)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
homeownership	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
paid employment	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
unpaid employment	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
business ownership	No	No	No	No	Yes	Yes	Yes	Yes	Yes
all household income sources	No	No	No	No	No	Yes	Yes	Yes	Yes
house subsidy beneficiaries	No	No	No	No	No	No	Yes	Yes	Yes
house price (log)	No	No	No	No	No	No	No	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	867,481	867,481	867,481	867,481	867,481	867,481	867,481	724,109	724,109
R^2	0.1301	0.1638	0.1665	0.1665	0.1674	0.1731	0.1733	0.1519	0.1519
Within R^2	0.0756	0.1114	0.1142	0.1143	0.1152	0.1213	0.1215	0.1023	0.1023
Bootstrap t-stat	#	#	#	#	#	#	#	#	-8.2950
Bootstrap-t $CI(95\%)$	#	#	#	#	#	#	#	#	[-10.151, -6.333]

NOTES: This table is got from estimating Equation 1. It compares littering in treated low-income households to a subgroup of the never-treated low- and middle-income households without grid connection but own NEES appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Littering is a dummy that is unity if a household reported that environmental littering is a problem. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 38: Selection Checks on the Effect of NEES on Land Degradation

land degradation	1	2	3	4	5	6	7	8	9
treated	-0.0059	-0.0059	-0.0059	-0.0059	-0.0059	-0.0059	-0.0058	-0.0096**	-0.0096**
	(0.0035)	(0.0035)	(0.0035)	(0.0035)	(0.0035)	(0.0035)	(0.0035)	(0.0041)	(0.0015)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
homeownership	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
paid employment	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
unpaid employment	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
business ownership	No	No	No	No	Yes	Yes	Yes	Yes	Yes
all household income sources	No	No	No	No	No	Yes	Yes	Yes	Yes
house subsidy beneficiaries	No	No	No	No	No	No	Yes	Yes	Yes
house price (log)	No	No	No	No	No	No	No	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	870,148	870,148	870,148	870,148	870,148	870,148	870,148	733,516	733,516
R^2	0.0187	0.0187	0.0187	0.0187	0.0187	0.0188	0.0189	0.0222	0.0222
Within R^2	0.0087	0.0087	0.0087	0.0087	0.0087	0.0088	0.0090	0.0094	0.0094
Bootstrap t-stat	#	#	#	#	#	#	#	#	-6.5744
Bootstrap-t $CI(95\%)$	#	#	#	#	#	#	#	#	[-9.437, -4.060]

NOTES: This table is got from estimating Equation 1. It compares land degradation in treated low-income households to a subgroup of the never-treated low- and high-income households without grid connection and do not own any NEES appliance. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Land degrade is a dummy that is unity if a household reported that land degradation is an environmental problem. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 39: Selection Checks on the Effect of NEES on Asbestos

asbestos	1	2	3	4	5	6	7	8	9
treated	-0.0353***	-0.0360***	-0.0361***	-0.0361***	-0.0361***	-0.0355***	-0.0357***	-0.0336***	-0.0336***
	(0.0079)	(0.0079)	(0.0079)	(0.0078)	(0.0078)	(0.0078)	(0.0077)	(0.0078)	(0.0039)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
homeownership	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
paid employment	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
unpaid employment	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
business ownership	No	No	No	No	Yes	Yes	Yes	Yes	Yes
all household income sources	No	No	No	No	No	Yes	Yes	Yes	Yes
house subsidy beneficiaries	No	No	No	No	No	No	Yes	Yes	Yes
house price (log)	No	No	No	No	No	No	No	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	826,121	826,121	826,121	826,121	826,121	826,121	826,121	693,379	693,379
R^2	0.1708	0.1722	0.1722	0.1722	0.1724	0.1727	0.1733	0.1895	0.1902
Within R^2	0.0811	0.0827	0.0827	0.0827	0.0829	0.0832	0.0839	0.0946	0.0954
Bootstrap t-stat	#	#	#	#	#	#	#	#	-8.6285
Bootstrap-t $CI(95\%)$	#	#	#	#	#	#	#	#	[-11.045, -6.196]

NOTES: This table is got from estimating Equation 1. It compares asbestos in treated low-income households to a subgroup of the never-treated middle- and high-income households without grid connection and do not own any NEES appliance. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Asbestos is a dummy that is unity if a household reported using asbestos (a type of poor roofing material) as a roofing material. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

6.2.4 Selection Issues on Health Outcomes

Table 40: Selection Checks on the Effect of NEES on Non-chronic Morbidity

non-chronic morbidity	1	2	3	4	5	6	7	8	9	10
treated	-0.0550***	-0.0520***	-0.0536***	-0.0536***	-0.0537***	-0.0508***	-0.0363***	-0.0381***	-0.0465***	-0.0465***
	(0.0125)	(0.0102)	(0.0108)	(0.0108)	(0.0107)	(0.0104)	(0.0069)	(0.0059)	(0.0074)	(0.0034)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
homeownership	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
paid employment	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
unpaid employment	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
business ownership	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
all household income sources	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
pollution	No	No	No	No	No	No	Yes	Yes	Yes	Yes
house subsidy beneficiaries	No	No	No	No	No	No	No	Yes	Yes	Yes
house price (log)	No	No	No	No	No	No	No	No	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	394,817	394,817	394,817	394,817	394,817	394,817	394,817	394,817	336,317	336,317
R^2	0.2738	0.3246	0.3428	0.3428	0.3428	0.3650	0.5404	0.5408	0.5126	0.5126
Within R^2	0.1415	0.2015	0.2230	0.2230	0.2242	0.2493	0.4566	0.4571	0.4392	0.4392
Bootstrap t-stat	#	#	#	#	#	#	#	#	#	-13.5462
Bootstrap-t $CI(95\%)$	#	#	#	#	#	#	#	#	#	[-15.590, -11.400]

NOTES: This table is got from estimating Equation 1. It compares non-chronic morbidity among individuals in treated low-income households to the never-treated low- and middle-income households. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Non-chronic morbidity is a dummy that is unity if an individual suffers from either flu/respiratory infections, diarrhoea, severe TBC, alcohol-related illness, mental illness or depression and any STDs. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 41: Selection Checks on the Effect of NEES on Respiratory Infections

respiratory infection	1	2	3	4	5	6	7	8	9	10
treated	-0.0066	-0.0062	-0.0062	-0.0061	-0.0061	-0.0060	-0.0051	-0.0050	-0.0054	-0.0054
	(0.0044)	(0.0044)	(0.0044)	(0.0044)	(0.0044)	(0.0043)	(0.0041)	(0.0041)	(0.0054)	(0.0018)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
homeownership	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
paid employment	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
unpaid employment	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
business ownership	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
all household income sources	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
pollution	No	No	No	No	No	No	Yes	Yes	Yes	Yes
house subsidy beneficiaries	No	No	No	No	No	No	No	Yes	Yes	Yes
house price (log)	No	No	No	No	No	No	No	No	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	335,485	335,485	335,485	335,485	335,485	335,485	335,485	335,485	284,779	284,779
R^2	0.0168	0.0179	0.0191	0.0191	0.0191	0.0203	0.0253	0.0253	0.0249	0.0249
Within R^2	0.0046	0.0057	0.0069	0.0069	0.0069	0.0081	0.0132	0.0132	0.0137	0.0137
Bootstrap t-stat	#	#	#	#	#	#	#	#	#	-3.1033
Bootstrap-t $CI(95\%)$	#	#	#	#	#	#	#	#	#	[-6.143, -0.076]

NOTES: This table is got from estimating Equation 1. It compares respiratory infection among individuals in treated low-income households to a subgroup of the never-treated low-, middle and high-income households without grid connection but own NEES recommended appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Flu/respiratory infection is a dummy that is unity if an individual suffers from a flu/respiratory disease, and zero otherwise. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 42: Selection Checks on the Effect of NEES on Diarrhoea

diarrhoea	1	2	3	4	5	6	7	8	9	10
treated	-0.0022*	-0.0022*	-0.0022*	-0.0022*	-0.0022*	-0.0022*	-0.0022*	-0.0022*	-0.0020*	-0.0020*
	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0007)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
homeownership	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
paid employment	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
unpaid employment	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
business ownership	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
all household income sources	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
pollution	No	No	No	No	No	No	Yes	Yes	Yes	Yes
house subsidy beneficiaries	No	No	No	No	No	No	No	Yes	Yes	Yes
house price (log)	No	No	No	No	No	No	No	No	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	376,865	376,865	376,865	376,865	376,865	376,865	376,865	376,865	321,140	321,140
R^2	0.0041	0.0041	0.0042	0.0042	0.0042	0.0042	0.0043	0.0043	0.0041	0.0041
Within R^2	0.0004	0.0004	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0006	0.0006
Bootstrap t-stat	#	#	#	#	#	#	#	#	#	-2.8933
Bootstrap-t $CI(95\%)$	#	#	#	#	#	#	#	#	#	[-5.259, -0.440]

NOTES: This table is got from estimating Equation 1. It compares diarrhoea among individuals in treated low-income households to a subgroup of the never-treated low-, middle- and high-income households without grid connection and do not own any NEES recommended appliance. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Diarrhoea is a dummy that is unity if an individual suffers from a diarrhoea, and zero otherwise. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 43: Selection Checks on the Effect of NEES on Severe Tuberculosis

Tuberculosis	1	2	3	4	5	6	7	8	9	10
treated	-0.0563***	-0.0514***	-0.0530***	-0.0530***	-0.0531***	-0.0505***	-0.0358***	-0.0378***	-0.0478***	-0.0478***
	(0.0146)	(0.0125)	(0.0128)	(0.0128)	(0.0128)	(0.0124)	(0.0071)	(0.0063)	(0.0078)	(0.0034)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
homeownership	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
paid employment	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
unpaid employment	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
business ownership	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
all household income sources	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
pollution	No	No	No	No	No	No	Yes	Yes	Yes	Yes
house subsidy beneficiaries	No	No	No	No	No	No	No	Yes	Yes	Yes
house price (log)	No	No	No	No	No	No	No	No	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	394,937	394,937	394,937	394,937	394,937	394,937	394,937	394,937	336,418	336,418
R^2	0.2784	0.3300	0.3490	0.3490	0.3501	0.3715	0.5485	0.5490	0.5211	0.5211
Within R^2	0.1444	0.2057	0.2281	0.2281	0.2294	0.2548	0.4647	0.4653	0.4476	0.4476
Bootstrap t-stat	#	#	#	#	#	#	#	#	#	-13.9777
Bootstrap-t $CI(95\%)$	#	#	#	#	#	#	#	#	#	[-16.110, -11.730]

NOTES: This table is got from estimating Equation 1. It compares severe TBC among individuals in treated low-income households to the never-treated low-, middle- and high-income households. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Severe TBC is a dummy that is unity if an individual suffers from severe tuberculosis, and zero otherwise. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

Table 44: Selection Checks on the Effect of NEES on Depression

depression	1	2	3	4	5	6	7	8	9	10
treated	-0.0012*	-0.0012*	-0.0012*	-0.0012*	-0.0012*	-0.0012*	-0.0012*	-0.0012*	0.0010	0.0010
	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0007)	(0.0005)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
homeownership	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
paid employment	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
unpaid employment	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
business ownership	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
all household income sources	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
pollution	No	No	No	No	No	No	Yes	Yes	Yes	Yes
house subsidy beneficiaries	No	No	No	No	No	No	No	Yes	Yes	Yes
house price (log)	No	No	No	No	No	No	No	No	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	376,865	376,865	376,865	376,865	376,865	376,865	376,865	376,865	321,140	321,140
R^2	0.0071	0.0071	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0072	0.0072
Within R^2	0.0010	0.0010	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0011	0.0011
Bootstrap t-stat	#	#	#	#	#	#	#	#	#	-1.8755
Bootstrap-t $CI(95\%)$	#	#	#	#	#	#	#	#	#	[-4.889, 0.723]

NOTES: This table is got from estimating Equation 1. It compares depressions among individuals in treated low-income households to a subgroup of the never-treated low-, middle- and high-income households without grid connection and do not own any NEES recommended appliance. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. Depression is a dummy that is unity if an individual suffers from any form of mental illness or depression. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level in all columns. I further report the one-way cluster robust standard errors from the median bootstrap t-statistic, and 95% confidence intervals in column 4, after 1000 bootstrap replications. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. # means no results.

6.3 Alternative Clustering of the SEs

This subsection tests whether the recovered results are sensitive to alternative clustering of the standard errors. Except for house prices, the results in Tables 45, 46, 47, and 48 are robust to different levels of clustering the standard errors.

Table 45: Effect of NEES on Energy Efficiency Adoption and Domestic Grid Usage: Alternative Clustering of the SEs

adoption and usage	NEES Adoption					Domestic Grid Usage				
	1	2	3	4	5	6	7	8	9	10
treated	0.0182***	0.0182**	0.0182***	0.0182***	0.0182**	0.0091*	0.0091	0.0091*	0.0091*	0.0091
	(0.0060)	(0.0084)	(0.0060)	(0.0060)	(0.0084)	(0.0053)	(0.0059)	(0.0053)	(0.0053)	(0.0059)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
year x province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
cluster at the:	h	v	h and v	h and p	v and p	h	v	h and v	h and p	v and p
Observations	901,592	901,592	901,592	901,592	901,592	871,485	871,485	871,485	871,485	871,485
R^2	0.0937	0.0937	0.0937	0.0937	0.0937	0.0741	0.0741	0.0741	0.0741	0.0741

NOTES: The Table is obtained from estimating equation 1. Robust standard errors are clustered at the province level in all columns. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. h, v and p denote household, village and provices, respectively.

Table 46: Effect of NEES on House Prices and Monthly Rents: Alternative Clustering of the SEs

house price and rents (log)	House Prices					Monthly Rents				
	1	2	3	4	5	6	7	8	9	10
treated	0.0332	0.0332	0.0332	0.0332	0.0332	0.0803**	0.0803*	0.0803**	0.0803**	0.0803*
	(0.0242)	(0.0290)	(0.0242)	(0.0242)	(0.0290)	(0.0366)	(0.0413)	(0.0366)	(0.0366)	(0.0413)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
year x province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
cluster at the:	h	v	h and v	h and p	v and p	h	v	h and v	h and p	v and p
Observations	559,124	559,124	559,124	559,124	559,124	51,547	51,547	51,547	51,547	51,547
R^2	0.3478	0.3478	0.3478	0.3478	0.3478	0.1581	0.1581	0.1581	0.1581	0.1581

NOTES: The Table is obtained from estimating equation 1. Robust standard errors are clustered at the province level in all columns. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. h, v and p denote household, village and provinces, respectively.

Table 47: Effect of NEES on Pollution Outcomes: Allternative Clustering of the SEs

Pollution (A)	Pollution					Air					Water				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
treated	-0.0596***	-0.0596***	-0.0596***	-0.0596***	-0.0596***	-0.0492***	-0.0492***	-0.0492***	-0.0492***	-0.0492***	-0.0757***	-0.0757***	-0.0757***	-0.0757***	-0.0757***
	(0.0110)	(0.0133)	(0.0110)	(0.0110)	(0.0133)	(0.0105)	(0.0139)	(0.0105)	(0.0105)	(0.0139)	(0.0127)	(0.0148)	(0.0127)	(0.0127)	(0.0148)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
year x province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
cluster at the:	h	v	h and v	h and p	v and p	h	v	h and v	h and p	v and p	h	v	h and v	h and p	v and p
Observations	867,481	867,481	867,481	867,481	867,481	901,092	901,092	901,092	901,092	901,092	901,592	901,592	901,592	901,592	901,592
R^2	0.1177	0.1177	0.1177	0.1177	0.1177	0.1567	0.1567	0.1567	0.1567	0.1567	0.2245	0.2245	0.2245	0.2245	0.2245
Pollution (B)	Littering					Land Degradation					Asbestos Exposure				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
treated	-0.0630***	-0.0630***	-0.0630***	-0.0630***	-0.0630***	-0.0059	-0.0059	-0.0059	-0.0059	-0.0059	-0.0353***	-0.0353***	-0.0353***	-0.0353***	-0.0353***
	(0.0113)	(0.0134)	(0.0113)	(0.0113)	(0.0134)	(0.0037)	(0.0058)	(0.0037)	(0.0037)	(0.0058)	(0.0082)	(0.0119)	(0.0082)	(0.0082)	(0.0119)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
year x province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
cluster at the:	h	v	h and v	h and p	v and p	h	v	h and v	h and p	v and p	h	v	h and v	h and p	v and p
Observations	867,481	867,481	867,481	867,481	867,481	870,148	870,148	870,148	870,148	870,148	826,121	826,121	826,121	826,121	826,121
R^2	0.1301	0.1301	0.1301	0.1301	0.1301	0.0187	0.0187	0.0187	0.0187	0.0187	0.1708	0.1708	0.1708	0.1708	0.1708

NOTES: The Table is obtained from estimating equation 1. Robust standard errors are clustered at the province level in all columns. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. h, v and p denote household, village and provinces, respectively.

Table 48: Effect of NEES on Pollution Outcomes: Alternative Clustering of the SEs

Non-chronic morbidity (A)	Non-chronic Morbidity					Respiratory Infection					Diarrhoea				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
treated	-0.0550***	-0.0550***	-0.0550***	-0.0550***	-0.0550***	-0.0066*	-0.0066	-0.0066*	-0.0066*	-0.0066	-0.0022**	-0.0022**	-0.0022**	-0.0022**	-0.0022**
	(0.0108)	(0.0153)	(0.0108)	(0.0108)	(0.0153)	(0.0038)	(0.0040)	(0.0038)	(0.0038)	(0.0040)	(0.0009)	(0.0009)	(0.0009)	(0.0009)	(0.0009)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
year x province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
cluster at the:	h	v	h and v	h and p	v and p	h	v	h and v	h and p	v and p	h	v	h and v	h and p	v and p
Observations	394,817	394,817	394,817	394,817	394,817	335,485	335,485	335,485	335,485	335,485	376,865	376,865	376,865	376,865	376,865
R^2	0.2738	0.2738	0.2738	0.2738	0.2738	0.0168	0.0168	0.0168	0.0168	0.0168	0.0041	0.0041	0.0041	0.0041	0.0041

Non-chronic morbidity (A)	Severe TBC					Depression/mental illness				
	1	2	3	4	5	6	7	8	9	10
treated	-0.0563***	-0.0563***	-0.0563***	-0.0563***	-0.0563***	-0.0012*	-0.0012*	-0.0012*	-0.0012*	-0.0012*
	(0.0108)	(0.0154)	(0.0108)	(0.0108)	(0.0154)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
year x province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
cluster at the:	h	v	h and v	h and p	v and p	h	v	h and v	h and p	v and p
Observations	394,937	394,937	394,937	394,937	394,937	376,865	376,865	376,865	376,865	376,865
R^2	0.2784	0.2784	0.2784	0.2784	0.2784	0.0071	0.0071	0.0071	0.0071	0.0071

NOTES: The Table is obtained from estimating equation 1. Robust standard errors are clustered at the province level in all columns. ***, ** and * denote less than 0.1%, 5% and 10% significance levels. h, v and p denote household, village and provinces, respectively.

6.4 Pre-Trends Tests

This subsection discusses the results of the pre-trends tests. Table 49 shows that the dynamic results discussed above show no evidence of significant pre-trends. Thus, this increases the confidence that the standard deviations observed on the outcomes in the post-treatment periods are indeed only caused by the NEES programme.

Table 49: Testing Parallel Pre-Trends Assumption on the Outcomes

Panel A:	Adoption & Grid Usage		Property Values and Rents			
Dependent Vars:	nees adoption	grid usage	house price	house price (log)	monthly rents	monthly rents (log)
Controls & all FEs	Yes	Yes	Yes	Yes	Yes	Yes
F-Statistic $(\chi^2) : \sum_{e=2005}^{2009} \beta_e = 0$	2.3252	2.7258	3.3223	3.4359	5.0208	3.6515
Two-sided p-values	0.3127	0.2559	0.5054	0.4877	0.1703	0.4552

Panel B:	Pollution						
Dependent Vars:	pollution	air	water	noise	littering	land degradation	asbestos
Controls & all FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-Statistic $(\chi^2) : \sum_{e=2005}^{2009} \beta_e = 0$	6.9450	7.5728	7.7688	7.8021	8.1485	3.8705	8.2730
Two-sided p-values	0.2248	0.1814	0.1694	0.1675	0.1482	0.2758	0.1418

Panel C:	Non-chronic Morbidity						
Dependent Vars:	non-chronic	respiratory	diarrhoea	severe TBC	alcoholism	STD	mental
Controls & all FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-Statistic $(\chi^2) : \sum_{e=2005}^{2009} \beta_e = 0$	8.0261	7.5290	3.6047	4.7464	6.0674	7.9439	3.5541
Two-sided p-values	0.1548	0.1842	0.3074	0.3143	0.2997	0.1594	0.6152

NOTES: The tests results come from estimating equation 1 and $e \neq 2010$. All equations are quadratic in number of rooms. Robust standard errors are clustered at the village level in all columns. ***, ** and * denote less than 0.1%, 5% and 10% significance levels.

6.5 Alternative Model Specifications

6.5.1 Alternative Quasi-Experimental Design

I use an alternative event-study design as one of the alternative specifications for robustness checks. Here, I assume that treatment timing is homogeneous in the sample. The event study model for this design is as follows:

$$\begin{aligned} Z_{j,h,v,p,t} = \sum_{e=2005}^{2009} \sum_{e=2011}^{2018} \delta_e \left(Eligible \cdot Post\right)_{h,v,p,t} + \beta_1 Post_t + \beta_2 Grid_{h,v,p,t} + \beta_3 DU_{h,v,p,t} \\ + \beta_4 NEESAPP_{h,v,p,t} + \beta_5 LincH_{h,v,p,t} + \phi P_{j,h,v,p,t} + \omega H_{h,v,p,t} \\ + \lambda_t + \delta_p + \theta_{p,t} + \varepsilon_{j,h,v,p,t}, \end{aligned} \tag{4}$$

where $Post_t$ is a dummy that is unity for post-treatment periods and zero, otherwise. $Eligible_{h,v,p,t}(0,1)$ is a dummy interaction for Low-income households, $LincH_{h,v,p,t}(0,1)$, who are treated if they have grid connection, $Grid_{h,v,p,t}(0,1)$, use electricity for domestic purposes, $DU_{h,v,p,t}(0,1)$, such as either lighting, cooking or heating, and either own any NEES recommended appliance, reduced their energy consumption during peak times or exhibit energy efficient behaviours, in terms of switching off their appliances after use or when leaving their house, $NEESAPP_{h,v,p,t}(0,1)$. The event study results in Figures 7, show robustness to different alternative quasi-experimental design.

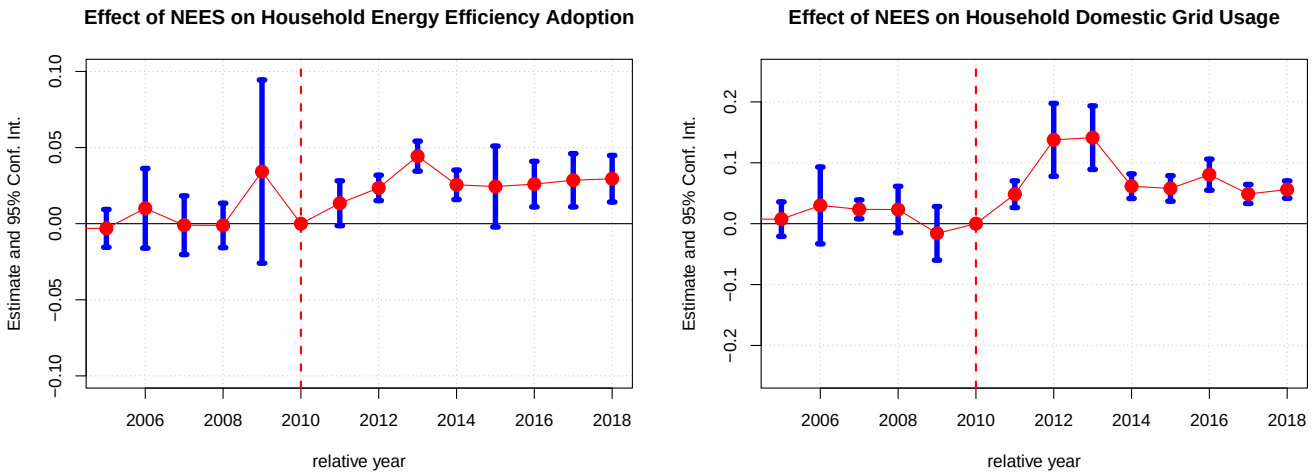


Figure 7: Effect of NEES on Energy Efficiency Adoption and Domestic Grid Usage

NOTES: This figure is obtained from estimating Equation 4 and compares the effect of NEES on energy efficiency adoption in treated low-income to the never-treated low- and middle-income households. The effect on domestic grid usage is compared to a subgroup of the never-treated middle- and high-income households without grid connection and do not own NEES recommended appliances. All equations are quadratic in number of rooms. Energy efficiency adoption is a dummy that is unity if households either own NEES recommended appliances, reduced their energy consumption during peak demand or exhibit energy efficiency behaviours, because of their grid connection and zero otherwise. Household domestic grid usage is a dummy that is unity if a household has a grid connection and uses it for domestic activities such as heating, cooking and lighting purposes, and zero otherwise. Robust standard errors are clustered at the village level.

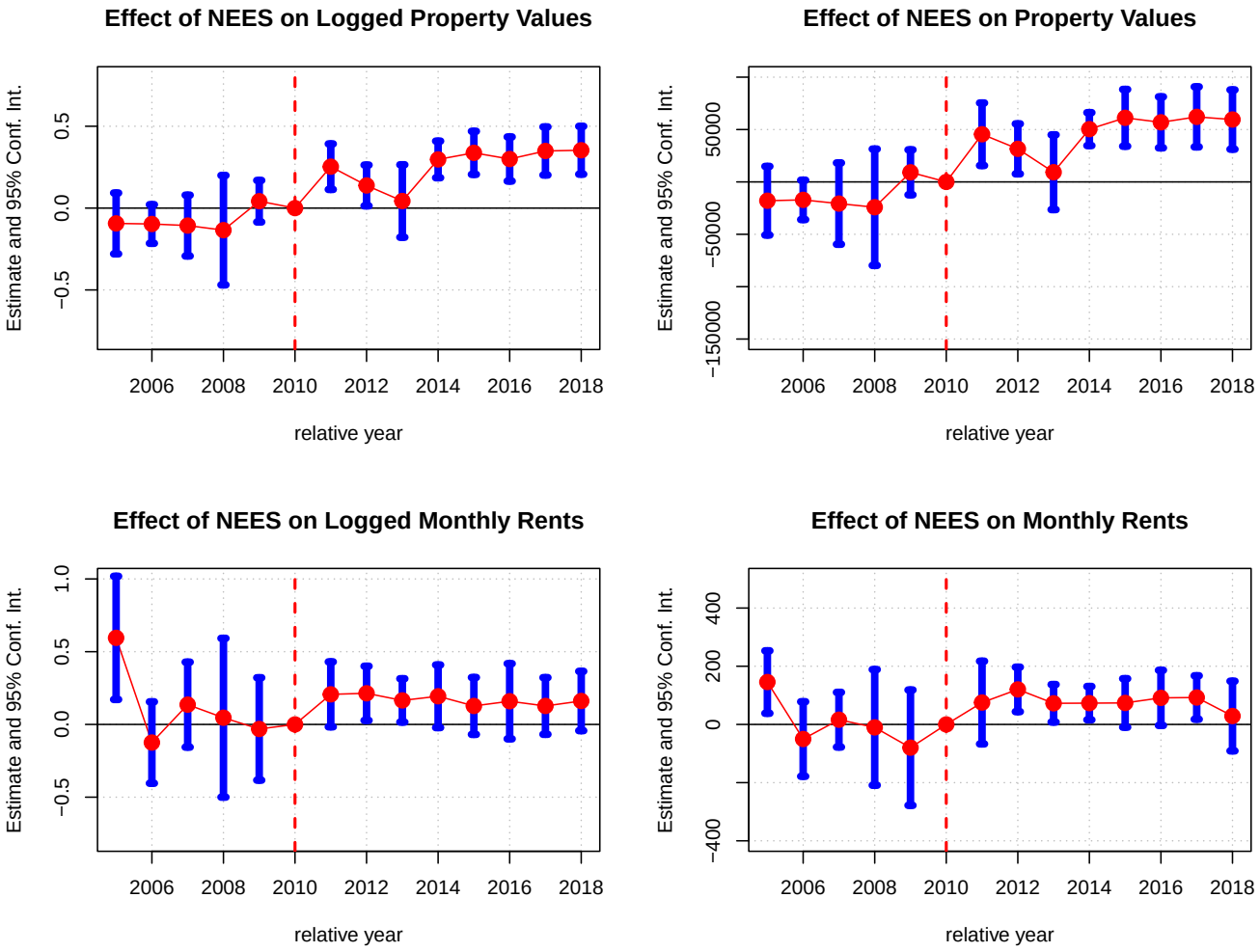


Figure 8: Effect of NEES on House Prices and Monthly Rents

NOTES: This figure is obtained from estimating Equation 4 and compares the effect of NEES on monthly rents in treated low-income to the never-treated middle- and high-income households. The effect on property values is compared to a subgroup of the never-treated low-, middle- and high-income households without grid connection and do not own NEES recommended appliances. All equations are quadratic in number of rooms. Property values and rents are self-reported time series of estimated market house prices and monthly house rents. Robust standard errors are clustered at the village level.

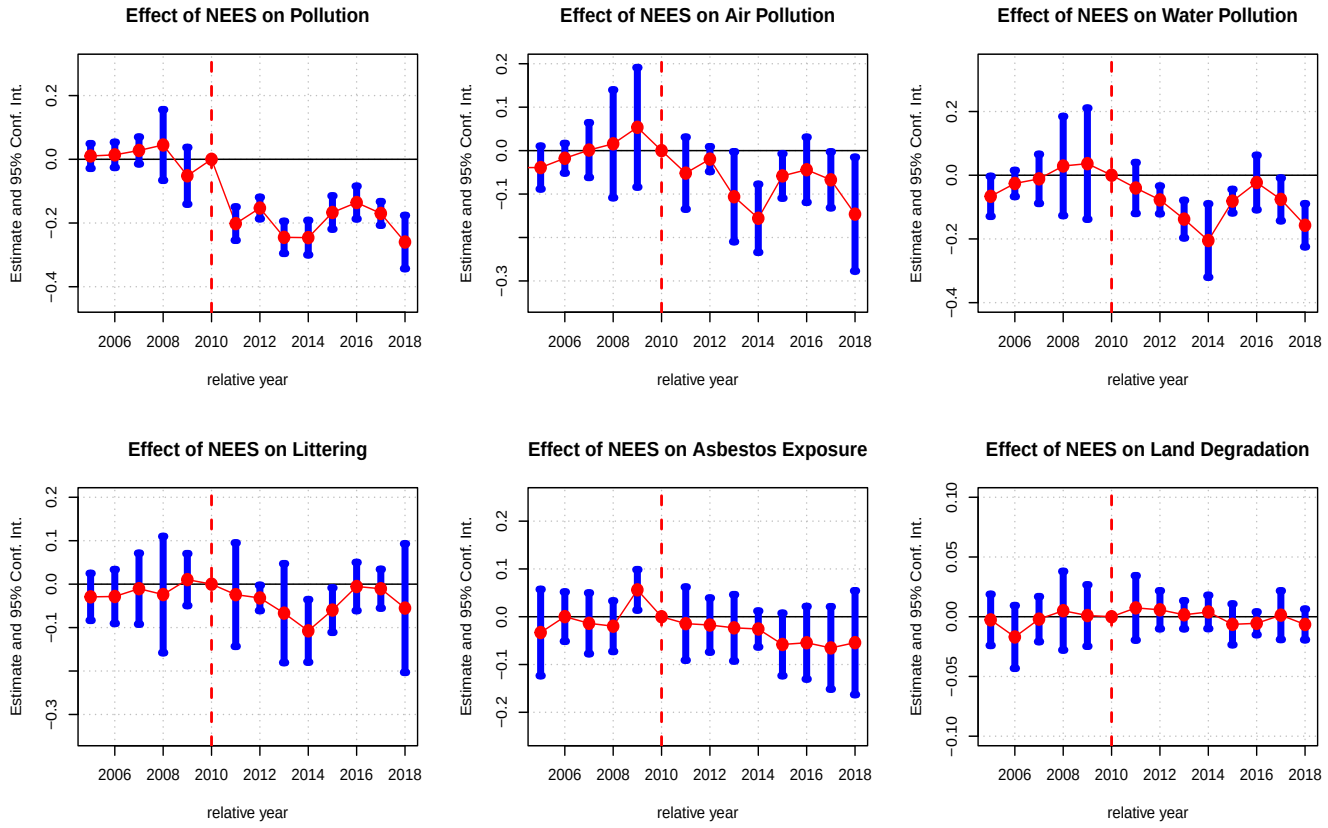


Figure 9: Effect of NEES on Pollution Outcomes

NOTES: This figure is got from estimating Equation 1 and presents the effect of NEES on pollution outcomes—air, water, littering, noise pollution and land degradation. It compares pollution outcomes of the treated low-income households to a subgroup of the never-treated middle- and high-income households without grid connection but own NEES appliances, except for littering and noise pollution that are compared to the never-treated middle-income households. All equations are quadratic in number of rooms. Pollution is a dummy that is unity if they reported that either littering, air, water or noise pollution is an environmental problem. Land degradation is a dummy that is unity if households reported that land degradation is an environmental problem. Robust standard errors are clustered at the village level.

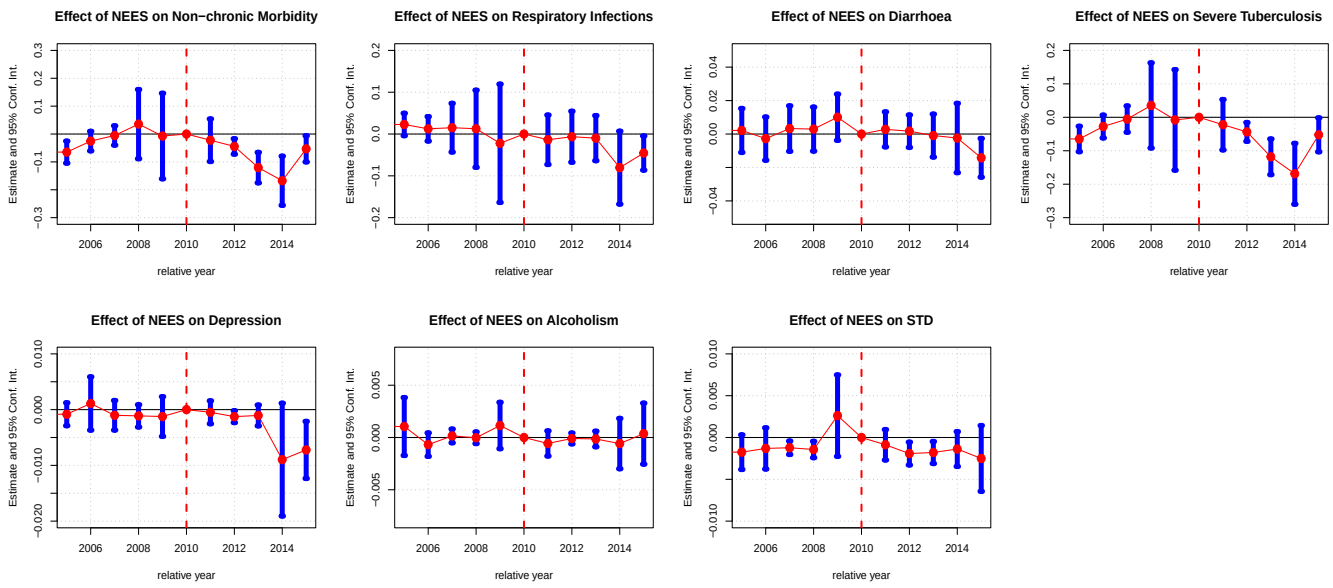


Figure 10: Event Study Plots of the Effect of NEES on Non-chronic Morbidity

NOTES: This figure is obtained from estimating Equation 4 and compares the effect of NEES on non-chronic morbidity in treated low-income households to the never-treated middle- and high-income households without grid connection but own NEES recommended appliances. The effect on diarrhoea, alcoholism and depression are compared to a subgroup of the never-treated low-, middle- and high-income households without grid connection and do not own NEES recommended appliances. Whereas, the effect on respiratory infections, severe tuberculosis and STDs are compared to the never-treated low- and high-income, middle- and high-income, and low-income households, respectively. Non-chronic morbidity is a dummy that is unity if an individual suffers from either flu/respiratory infections, diarrhoea, severe tuberculosis, alcohol-related illness, mental illness and any sexual transmitted diseases (STDs). All equations are quadratic in number of rooms. Robust standard errors are clustered at the village level.

6.5.2 Probit Specification

Further, I specify a probit model of the form in Section 5 retaining all the left- and right-hand-side (LHS and RHS) variables and definitions, except for programme adoption and grid usage. $\mho$ is the cumulative normal density function. The results in Table 50 again show robustness to this specifications.

$$\begin{aligned} Pr\left(Z_{j,h,v,p,t} \mid \left[Treated^{e}_{h,v,p,t}, Controls_{j,h,v,p,t}\right]\right) = \mho\big(&\beta_1 Treated^{e}_{h,v,p,t} + \beta_2 Grid_{h,v,p,t} + \beta_3 DU_{h,v,p,t} \\ &+\beta_4 NEESAPP_{h,v,p,t} + \beta_5 LincH_{h,v,p,t} + \phi P_{j,h,v,p,t} \\ &+\omega H_{h,v,p,t} + \lambda_t + \delta_p + \theta_{p,t} + \varepsilon_{j,h,v,p,t}\big) \end{aligned} \tag{5}$$

Table 50: Effect of NEES on Adoption, Grid Usage, Pollution and Non-chronic Morbidity Outcomes

	Adoption and Grid Usage		Pollution						Non-chronic Morbidity				
	1	2	3	4	5	6	7	8	9	10	11	12	13
Dependent Var	nees adopt	grid usage	pollution	air	water	littering	land degrade	asbestos	non-chronic	respiratory	diarrhoea	tuberculosis	depression
treated	0.0424	0.0755	-0.0334	-0.0708	-0.1452*	-0.1067**	-0.0982***	-0.2115***	-0.0917*	-0.1378**	-0.1681**	-0.0928*	-0.1958**
	(0.0585)	(0.0828)	(0.0663)	(0.0509)	(0.0837)	(0.0428)	(0.0231)	(0.0224)	(0.0538)	(0.0573)	(0.0728)	(0.0555)	(0.0693)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
year x province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	901,592	899,242	901,092	901,092	901,592	867,481	825,083	825,849	394,817	335,485	370,445	394,937	367,298
R^2	0.1133	0.1032	0.1029	0.1584	0.2409	0.1220	0.0208	0.2244	0.2941	0.0158	0.0039	0.2991	0.0047
Pseudo R^2	0.1567	0.1992	0.0897	0.1270	0.1881	0.1162	0.1167	0.2725	0.2280	0.0657	0.0474	0.2322	0.1415

NOTES: This table is got from estimating Equation 5. It compares programme adoption, grid usage, pollution and non-chronic morbidity in treated low-income households to the never-treated low-, middle- and high-income households. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level. ***, ** and * denote less than 0.1%, 5% and 10% significance levels.

6.5.3 Two-Stage Difference-in-Differences Specification

Following the work of Gardner (2022), I specify a two-stage difference-in-differences model retaining all the LHS and RHS definitions as is in equation 1 but with less restrictions in the fixed effects. This model estimates a simple difference-in-differences model accounting for possible negative weighting associated with the TWFE estimator when there are staggered treatment adoption. All RHS variables and vectors are as defined in Section 5. The results in Table 51 again show robustness to this specifications.

$$Z_{j,h,v,p,t} = \beta_1 Treated^{e}_{h,v,p,t} + \beta_2 Grid_{h,v,p,t} + \beta_3 DU_{h,v,p,t} + \beta_4 NEESAPP_{h,v,p,t} + \beta_5 LincH_{h,v,p,t} + \phi P_{j,h,v,p,t} + \omega H_{h,v,p,t} + \lambda_t + \delta_p + \varepsilon_{j,h,v,p,t}, \quad (6)$$

Table 51: Effects of NEES on the Outcomes

	Adoption & Usage		House Prices & Rents				Pollution Outcomes						Non-chronic Morbidity				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Dependent Var	nees adopt	grid usage	house price	house price (log)	rents	rents (log)	pollution	air	water	littering	land degrade	asbestos	non-chronic	respiratory	diarrhoea	tuberculosis	depression
treated	0.0174	0.0441***	25,537.7*	0.1558*	25.19	0.0065	-0.0368	-0.0796***	-0.0890***	-0.1312***	-0.0059*	-0.0571***	-0.0589***	0.0060	-0.0029*	-0.0587***	-0.0013**
	(0.0109)	(0.0061)	(13,553.0)	(0.0880)	(16.85)	(0.0253)	(0.0334)	(0.0303)	(0.0279)	(0.0206)	(0.0034)	(0.0115)	(0.0158)	(0.0040)	(0.0015)	(0.0168)	(0.0006)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	976,550	871,485	757,901	757,901	52,896	52,896	974,396	974,396	976,550	869,331	901,396	871,485	394,817	394,937	394,937	394,937	394,937
R^2	0.0005	0.0039	0.0047	0.0061	0.0011	9.83e-7	0.0013	0.0059	0.0093	0.0112	0.0003	0.0061	0.0043	0.0003	0.0004	0.0043	0.0002
Adj. R^2	0.0005	0.0039	0.0047	0.0061	0.0011	9.83e-7	0.0013	0.0059	0.0093	0.0112	0.0003	0.0061	0.0043	0.0003	0.0004	0.0043	0.0002

NOTES: This table is got from estimating Equation 6 and compares all outcomes of the treated low-income households to the never-treated households. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender-male vs female, marital status-married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. All equations are quadratic in number of rooms. Robust standard errors are clustered at the province level in all columns. ***, ** and * denote less than 0.1%, 5% and 10% significance levels.

7 Heterogeneous Analysis

For targeted policies, this section discusses the heterogeneous characterisations of the above effects. For the adoption of the NEES programme, Table 52 shows that energy efficiency adoption is strongest among low-income Blacks and Asians/Indians living in metropolitan areas in South Africa, especially in high- (Gauteng, Kwazulu-Natal, Western Cape) and low-density (North West, Free State, Northern Cape) populated provinces. However, the result also show that low-income White-renters in medium-populated provinces (Eastern Cape, Limpopo, Mpumalanga) are less likely to adopt the NEES programme. Similarly, due to NEES adoption, the higher domestic grid usage is dominated in urban areas of the high- and low-density populated provinces (Table 53). Further, Tables 54 and 55 show that the capitalisation in house prices and rents are strongest in metropolitan and urban areas of highly populated provinces. The environmental effects in panel A f Table 56 reports an ubiquitous pollution reductions, strongest in high-density provinces. These environmental improvements are in terms of air, water, littering, land degradation and asbestos exposure, particularly in urban metro- and non-metropolitan areas of high- and low-density provinces. Consequently, the public health gains in Table 57 are strongest in high-density provinces especially among adults, youths and children of low-income Blacks, Whites, and Coloured male and female individuals living in both rural and urban areas of metro- and non-metropolitan areas. This declining effect in respiratory infections, diarrhoea, severe tuberculosis and depression is strongest for the improvements in severe tuberculosis and diarrhoea, especially for low-income individuals living in both high- and low-dense provinces.

Table 52: Heterogeneous Effects of NEES on Energy Efficiency Adoption

	Homeownership		Race				Location				Provincial Population Sizes		
	1	2	3	4	5	6	7	8	9	10	11	12	13
Dependent Var	homeowners	renters	black	white	colored	asians	metro	non-metro	urban	rural	top	med	low
treated	0.0093	-0.0149*	0.0241*	-0.0044*	0.0429	0.0586***	0.0491***	0.0037	0.0207	0.0027	0.0348**	-0.0160***	0.0478*
	(0.0120)	(0.0078)	(0.0108)	(0.0019)	(0.0252)	(0.0117)	(0.0030)	(0.0117)	(0.0154)	(0.0133)	(0.0013)	(0.0007)	(0.0248)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	677,465	92,262	784,429	33,295	72,162	11,706	214,314	687,278	705,738	195,854	364,402	362,831	128,843
R^2	0.1102	0.0440	0.0943	0.0377	0.1356	0.0659	0.1192	0.0941	0.0948	0.1018	0.1043	0.0679	0.1194
Within R^2	0.0668	0.0212	0.0598	0.0102	0.0780	0.0121	0.0917	0.0561	0.0705	0.0294	0.0831	0.0575	0.0941

NOTES: This table is got from estimating Equation 1. It compares energy efficiency adoption in treated low-income households to a subgroup of the never-treated low-, middle- and high-income households without grid connection and do not own any NEES appliance. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution, and a type of house dummy. All equations are quartic in number of rooms. Energy efficiency adoption is a dummy that is unity if a household is connected to the grid and own any NEES recommended appliance, and zero otherwise. Robust standard errors are clustered at the province level in all columns. ***, ** and * denote less than 0.1%, 5% and 10% significance levels.

Table 53: Heterogeneous Effects of NEES on Domestic Grid Usage

	Homeownership		Race				Location				Provincial Population Sizes		
	1	2	3	4	5	6	7	8	9	10	11	12	13
Dependent Var	homeowners	renters	black	white	colored	asians	metro	non-metro	urban	rural	top	med	low
treated	0.0058	0.0026	0.0098	-0.0022	0.0179	-0.0038	0.0098	0.0081	0.0159**	0.0009	0.0118*	0.0071	0.0210*
	(0.0074)	(0.0041)	(0.0057)	(0.0017)	(0.0261)	(0.0037)	(0.0088)	(0.0081)	(0.0056)	(0.0098)	(0.0036)	(0.0178)	(0.0027)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	636,304	113,563	754,369	33,623	71,812	11,681	230,305	641,180	705,676	165,809	363,672	338,822	124,962
R^2	0.0763	0.0270	0.0739	0.0345	0.1282	0.0481	0.0902	0.0699	0.0783	0.0703	0.0771	0.0530	0.1020
Within R^2	0.0496	0.0133	0.0529	0.0065	0.0838	0.0112	0.0628	0.0498	0.0580	0.0256	0.0642	0.0454	0.0811

NOTES: This table is got from estimating Equation 1. It compares domestic grid usage in treated low-income households to the never-treated middle- and high-income households. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution, and a type of house dummy. All equations are quartic in number of rooms. Domestic grid usage is a dummy that is unity if a grid connected household uses the grid electricity supply for domestic purposes such as heating, cooking and lighting purposes, and zero otherwise. Robust standard errors are clustered at the province level in all columns. ***, ** and * denote less than 0.1%, 5% and 10% significance levels.

Table 54: Heterogeneous Effects on NEES on House/Flat Prices

	Homeownership		Location				Provincial Population Sizes		
	1	2	3	4	5	6	7	8	9
Dependent Var	homeowners	renters	metro	non-metro	urban	rural	top	med	low
treated	0.0168	0.0283	0.0311	0.0117	0.0342*	0.0089	0.0319*	0.0116	0.0092
	(0.0192)	(0.0190)	(0.0170)	(0.0214)	(0.0155)	(0.0224)	(0.0160)	(0.0225)	(0.0219)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	542,172	547,570	546,310	547,143	556,768	536,685	549,440	541,298	536,477
R^2	0.3454	0.3478	0.3489	0.3448	0.3476	0.3457	0.3460	0.3468	0.3462
Within R^2	0.2674	0.2795	0.2846	0.2665	0.2840	0.2660	0.2816	0.2676	0.2674

NOTES: The Table is obtained from estimating equation 1. It compares property values for treated low-income to a subgroup of the never-treated low- and high-income households without grid connection but own NEES recommended appliances. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. All equations are quartic in number of rooms. Property values are self-reported time series of estimated market house prices. Robust standard errors are clustered at the province level in all columns. ***, ** and * denote less than 0.1%, 5% and 10% significance levels.

Table 55: Heterogeneous Effects on NEES on House/Flat Rents

	Location				Provincial Population Sizes		
	1	2	3	4	5	6	7
Dependent Var	metro	non-metro	urban	rural	top	med	low
treated	0.0649*	0.0658	0.0739*	0.0547	0.0720**	0.0496	0.0557
	(0.0256)	(0.0364)	(0.0276)	(0.0370)	(0.0304)	(0.0357)	(0.0402)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	47,438	49,059	50,658	45,839	48,737	47,116	45,500
R^2	0.1473	0.1878	0.1509	0.1806	0.1538	0.1830	0.1699
Within R^2	0.0781	0.1036	0.0830	0.0944	0.0847	0.0868	0.0860

NOTES: The Table is obtained from estimating equation 1. It compares above-average monthly rents for a house/flat for the treated low-income to a subgroup of the never-treated low-income households without grid connection and do not own any NEES recommended appliance. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source, water pollution and a type of house dummy. All equations are quartic in number of rooms. Monthly rents are self-reported time series of estimated monthly house rents. Robust standard errors are clustered at the province level in all columns. ***, ** and * denote less than 0.1%, 5% and 10% significance levels.

Table 56: Heterogeneous Effects on NEES on Pollution Outcomes

	Panel A: Pollution							Panel B: Air Pollution						
	Location				Provincial Population Sizes			Location				Provincial Population Sizes		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
heterogeneous effects	metro	non-metro	urban	rural	top	med	low	metro	non-metro	urban	rural	top	med	low
treated	-0.0962***	-0.0357*	-0.0648***	-0.0319	-0.0782***	-0.0173	-0.0887	-0.1071***	-0.0277	-0.0479	-0.0306	-0.0583	-0.0415	-0.0476
	(0.0082)	(0.0175)	(0.0126)	(0.0259)	(0.0070)	(0.0112)	(0.0169)	(0.0083)	(0.0222)	(0.0272)	(0.0344)	(0.0274)	(0.0431)	(0.0293)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	228,660	638,821	703,379	164,102	362,814	336,010	124,596	214,075	687,017	705,343	195,749	364,085	362,741	128,761
R^2	0.1333	0.1014	0.1281	0.0905	0.1277	0.1102	0.0938	0.1417	0.1395	0.1607	0.1734	0.1559	0.1303	0.1245
Within R^2	0.1012	0.0474	0.0735	0.0297	0.0965	0.0459	0.0670	0.0799	0.0789	0.0781	0.0813	0.0850	0.0950	0.0915
	Panel C: Water Pollution							Panel D: Littering						
	Location				Provincial Population Sizes			Location				Provincial Population Sizes		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
heterogeneous effects	metro	non-metro	urban	rural	top	med	low	metro	non-metro	urban	rural	top	med	low
treated	-0.1284***	-0.0527*	-0.0819**	-0.0477	-0.1010*	-0.0449	-0.0815	-0.1054***	-0.0333	-0.0689***	-0.0259	-0.0848**	-0.0022	-0.1008*
	(0.0155)	(0.0244)	(0.0348)	(0.0311)	(0.0306)	(0.0490)	(0.0144)	(0.0114)	(0.0235)	(0.0193)	(0.0302)	(0.0145)	(0.0095)	(0.0110)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	214,314	687,278	705,738	195,854	364,402	362,831	128,843	228,660	638,821	703,379	164,102	362,814	336,010	124,596
R^2	0.2066	0.2209	0.2219	0.2794	0.2082	0.1961	0.2082	0.1466	0.1096	0.1414	0.0932	0.1424	0.1086	0.1226
Within R^2	0.0980	0.1190	0.0943	0.1436	0.1052	0.1303	0.1204	0.1142	0.0549	0.0839	0.0334	0.1102	0.0493	0.0736
	Panel E: Land Degradation							Panel F: Asbestos Usage						
	Location				Provincial Population Sizes			Location				Provincial Population Sizes		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
heterogeneous effects	metro	non-metro	urban	rural	top	med	low	metro	non-metro	urban	rural	top	med	low
treated	-0.0068**	-0.0084	-0.0058	-0.0023	-0.0049	-0.0102	0.0029	-0.0399*	-0.0314*	-0.0403**	-0.0247	-0.0463**	-0.0309	-0.0027
	(0.0021)	(0.0066)	(0.0054)	(0.0025)	(0.0026)	(0.0083)	(0.0050)	(0.0172)	(0.0148)	(0.0124)	(0.0169)	(0.0103)	(0.0114)	(0.0050)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	202,877	667,271	683,270	186,878	347,288	353,063	125,231	202,313	623,808	664,373	161,748	328,609	332,979	121,212
R^2	0.0184	0.0253	0.0188	0.0280	0.0152	0.0366	0.0146	0.1453	0.1848	0.1727	0.2021	0.1421	0.2575	0.0338
Within R^2	0.0087	0.0101	0.0085	0.0062	0.0075	0.0264	0.0074	0.0754	0.0486	0.0732	0.0339	0.0775	0.1937	0.0207

NOTES: This table is got from estimating Equation 1. It compares pollution in treated low-income households to a subgroup of the never-treated low-, middle- and high-income households without grid connection but own NEES appliances.The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. All equations are quartic in number of rooms. Robust standard errors are clustered at the province level. ***, ** and * denote less than 0.1%, 5% and 10% significance levels.

Table 57: Heterogeneous Effects of NEES on Non-chronic Morbidity

	Age Groups				Gender		Race				Location				Provincial Population Sizes		
Panel A: Non-chronic Morbidity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
heterogeneous effects	retirees	adults	youths	children	male	female	black	white	coloured	asians	metro	non-metro	rural	urban	top	medium	low
treated	0.0231	-0.0561***	-0.0640***	-0.0373*	-0.0601***	-0.0459**	-0.0583***	-0.0533**	-0.0551**	-0.0471	-0.0781***	-0.0425*	-0.0449*	-0.0704***	-0.0710**	-0.0349	-0.0896
	(0.0141)	(0.0134)	(0.0174)	(0.0182)	(0.0142)	(0.0194)	(0.0160)	(0.0175)	(0.0223)	(0.0277)	(0.0030)	(0.0194)	(0.0229)	(0.0106)	(0.0079)	(0.0263)	(0.0267)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	23,110	120,510	133,214	117,975	186,895	207,922	333,622	16,745	36,356	5,785	85,829	308,988	186,930	207,887	163,284	144,342	64,734
R^2	0.1839	0.2446	0.2878	0.2176	0.2829	0.2633	0.2927	0.1491	0.2066	0.1182	0.1918	0.2755	0.2688	0.2005	0.2440	0.2581	0.2553
Within R^2	0.0971	0.1233	0.1462	0.1498	0.1452	0.1350	0.1595	0.0817	0.0330	0.0291	0.1095	0.1570	0.1454	0.1042	0.1329	0.1720	0.1650
Panel B: respiratory infection																	
heterogeneous effects	retirees	adults	youths	children	male	female	black	white	coloured	asians	metro	non-metro	rural	urban	top	medium	low
treated	-0.0050	-0.0096	-0.0064	0.0001	-0.0077	-0.0016	-0.0065	-0.0388**	0.0195**	-0.0045	-0.0100*	-0.0035	-0.0036	-0.0073	-0.0096	0.0079	-0.0262
	(0.0032)	(0.0055)	(0.0063)	(0.0049)	(0.0063)	(0.0015)	(0.0046)	(0.0153)	(0.0076)	(0.0211)	(0.0039)	(0.0054)	(0.0052)	(0.0047)	(0.0043)	(0.0051)	(0.0065)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20,658	102,003	112,244	100,574	156,543	178,942	276,922	16,411	36,362	5,790	74,994	260,491	150,518	184,967	134,047	122,612	58,401
R^2	0.0143	0.0184	0.0222	0.0219	0.0158	0.0217	0.0187	0.0435	0.0218	0.0262	0.0152	0.0188	0.0236	0.0152	0.0156	0.0193	0.0240
Within R^2	0.0038	0.0039	0.0064	0.0120	0.0047	0.0047	0.0053	0.0081	0.0038	0.0088	0.0076	0.0037	0.0028	0.0046	0.0060	0.0076	0.0045
Panel C: diarrhea																	
heterogeneous effects	retirees	adults	youths	children	male	female	black	white	coloured	asians	metro	non-metro	rural	urban	top	medium	low
treated	0.0007	-0.0026**	-0.0009	-0.0061**	-0.0005	-0.0044**	-0.0023*	0.0032	-0.0079**	0.0014	-0.0033**	-0.0017	-0.0012	-0.0030***	-0.0023	-0.0023	-0.0013
	(0.0040)	(0.0008)	(0.0012)	(0.0026)	(0.0009)	(0.0017)	(0.0011)	(0.0049)	(0.0026)	(0.0025)	(0.0008)	(0.0014)	(0.0015)	(0.0007)	(0.0015)	(0.0011)	(0.0021)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	22,629	114,694	126,354	113,180	177,459	199,406	317,066	16,597	37,316	5,886	80,716	296,149	178,049	198,816	153,367	138,768	63,048
R^2	0.0123	0.0073	0.0053	0.0020	0.0038	0.0059	0.0041	0.0203	0.0116	0.0437	0.0042	0.0052	0.0047	0.0052	0.0031	0.0049	0.0076
Within R^2	0.0012	0.0010	0.0006	0.0011	0.0006	0.0004	0.0004	0.0020	0.0020	0.0011	0.0008	0.0004	0.0006	0.0005	0.0006	0.0009	0.0008
Panel D: tuberculosis																	
heterogeneous effects	retirees	adults	youths	children	male	female	black	white	coloured	asians	metro	non-metro	rural	urban	top	medium	low
treated	0.0091	-0.0565***	-0.0605**	-0.0594**	-0.0598***	-0.0486**	-0.0591***	-0.0655	-0.0668***	-0.0298	-0.0792***	-0.0461*	-0.0486*	-0.0711***	-0.0704**	-0.0314	-0.1105*
	(0.0321)	(0.0160)	(0.0198)	(0.0187)	(0.0170)	(0.0195)	(0.0173)	(0.0770)	(0.0198)	(0.0176)	(0.0040)	(0.0228)	(0.0256)	(0.0108)	(0.0111)	(0.0295)	(0.0097)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	23,114	120,540	133,233	118,042	186,974	207,963	333,726	16,750	38,523	5,938	85,862	309,075	186,986	207,951	163,349	144,380	64,748
R^2	0.1992	0.2501	0.2907	0.2215	0.2865	0.2686	0.2976	0.1524	0.2049	0.1205	0.1950	0.2807	0.2741	0.2049	0.2467	0.2643	0.2609
Within R^2	0.1042	0.1262	0.1482	0.1526	0.1480	0.1378	0.1627	0.0836	0.0431	0.0391	0.1117	0.1606	0.1490	0.1065	0.1350	0.1768	0.1690
Panel E: depression																	
heterogeneous effects	retirees	adults	youths	children	male	female	black	white	coloured	asians	metro	non-metro	rural	urban	top	medium	low
treated	-0.0118*	-0.0016*	-0.0004	0.0003*	-0.0006	-0.0019**	-0.0005	-0.0152**	-0.0018	0.0002	-0.0011***	-0.0014	-0.0005	-0.0015*	-0.0014	-0.0015	0.0004
	(0.0055)	(0.0008)	(0.0009)	(0.0001)	(0.0006)	(0.0008)	(0.0005)	(0.0051)	(0.0037)	(0.0002)	(0.0001)	(0.0008)	(0.0005)	(0.0007)	(0.0007)	(0.0013)	(0.0011)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
all FEs and LTs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	22,629	114,694	126,354	113,180	177,459	199,406	317,066	16,597	37,316	5,886	80,716	296,149	178,049	198,816	153,367	138,768	63,048
R^2	0.0109	0.0099	0.0103	0.0030	0.0083	0.0094	0.0081	0.0194	0.0139	0.0937	0.0117	0.0066	0.0066	0.0080	0.0078	0.0074	0.0061
Within R^2	0.0019	0.0013	0.0007	0.0016	0.0013	0.0009	0.0008	0.0056	0.0017	0.0025	0.0015	0.0009	0.0007	0.0013	0.0012	0.0011	0.0018

NOTES: This table is got from estimating Equation 1. It compares non-chronic morbidity among individuals in treated low-income households to the never-treated low-, middle- and high-income households. The controls include dummies of grid connection, domestic electricity usage, ownership of NEES appliances, low-income households, individual level variables such as age, dummies for gender—male vs female, marital status—married vs others; location variables—rural vs urban; race—black, white; beneficiaries of the house subsidy programme and land access; internal hedonic characteristics such as piped water into dwelling, number of rooms; external hedonic characteristics such as distance to school, toilet and water source and a type of house dummy. All equations are quartic in number of rooms. Non-chronic morbidity is a dummy that is unity if an individual suffers from either flu/respiratory infections, diarrhoea, severe TBC, alcohol-related illness, mental illness or depression and any STDs. Robust standard errors are clustered at the province level in all columns. ***, ** and * denote less than 0.1%, 5% and 10% significance levels.

8 Conclusions

This study set out to document the causal impact of NEES on several outcomes including grid usage, house prices and rents, pollution and health outcomes for a developing country. Using the traditional difference-in-differences estimator, I document a rebound effect due to NEES with attendant domino-effect across the housing market, environment and public health. Particularly, I find that energy efficiency is significantly capitalised in the housing market in terms of house prices and rents. Further, there is strong pollution reductions followed by a significant reductions in non-chronic morbidity among low-income South Africans. Reassuringly, several robustness checks showed that these findings are robust to different model

specifications and experimental design. Moreover, the potential mechanisms show that the housing market capitalisations are direct consequences of energy efficiency upgrades in terms of ownership of any NEES recommended appliances. For the pollution reductions, I find that efficient grid consumption directly explain the environmental improvements among the treated low-income households. Further, I argue that these environmental improvements are only but conduits for the realised public health gains due to the NEES programme, particularly for the reductions in severe tuberculosis, diarrhoea and respiratory infections. The diverse characteristics of these effects are analyzed with respect to policy objectives. Energy efficiency adoption among Black and Asian populations, as well as modern energy usage, is more prevalent in urbanized areas of both sparsely and densely populated provinces. This trend contributes to increasing housing prices and rental rates in these regions. While pollution reductions are widespread, they are particularly significant in densely populated metropolitan provinces. Consequently, this results in public health improvements for adults, youth, and children, across all genders, races, and locations within high-density provinces. However, I find that low-income White-renters in medium populated provinces (Eastern Cape, Limpopo, Mpumalanga) are less likely to adopt the NEES programme. Consequently, the effect NEES in this location is generally mute. Therefore, policy should target these particular provinces to increase energy efficiency adoption in order for the residents to take advantages of the benefits of energy efficiency upgrades.

Appendices

I Summary Statistics

Table 58: Summary Statistics between the Treated and Never-Treated Households

Summary Statistics	Before 2011						After 2011					
	Treated			Never-Treated			Treated			Never-Treated		
Variable	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Age	37.257	15	99	36.368	15	96	28.979	0	113	28.033	0	108
male	0.477	0	1	0.643	0	1	0.464	0	1	0.505	0	1
married	0.444	0	1	0.476	0	1	0.235	0	1	0.287	0	1
black	0.840	0	1	0.963	0	1	0.860	0	1	0.943	0	1
white	0.022	0	1	0.003	0	1	0.054	0	1	0.017	0	1
rural	0.256	0	1	0.438	0	1	0.143	0	1	0.198	0	1
Trad	0.046	0	1	0.179	0	1	0.096	0	1	0.143	0	1
water piped into dwellings	0.829	0	1	0.310	0	1	0.659	0	1	0.478	0	1
house proximity to school	0.007	0	1	0.009	0	1	0.257	0	1	0.196	0	1
house proximity to toilet	0.489	0	1	0.581	0	1	0.021	0	1	0.101	0	1
house proximity to water source	0.138	0	1	0.609	0	1	0.281	0	1	0.450	0	1
land access	0.048	0	1	0.102	0	1	0.020	0	1	0.022	0	1
number of rooms	3.441	0	60	2.468	0	21	5.592	1	20	2.730	1	20
water pollution	0.837	0	1	0.831	0	1	0.237	0	1	0.585	0	1

NOTES: This table compares summary statistics of the treated low-income households to the never-treated low-, middle- and high-income households.

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