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Abstract

We investigate the effectiveness of large electricity subsidies to reduce the consumption of dirty energy and improve ambient air quality. We exploit a policy change in Mongolia that provides 50–100 percent subsidy to households in some regions, allowing us to use difference-in-differences models. Using five rounds of the Mongolia Household Socio-Economic Survey, we find that the subsidy reduces the likelihood of reporting illness. We further find that households receiving the electricity subsidy increase their (total of subsidised and un-subsidised) electricity expenditure by at least 17 percent more than those who have not received any such benefit. This is an important positive outcome, indicating that households changed their behavior of daytime and non-winter season electricity consumption, when they do not receive any subsidy. Policymakers, therefore, need to internalize the unintended benefit of the subsidy when comparing with the cost of the programme.

Keywords: Electricity demand, Inequality of electricity access, Health, Development, Mongolia

JEL-Classification: D12, O13, Q41, Q53, Q56, L94

Declaration of interest: None.

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1. Introduction

Reducing greenhouse gas emissions and supporting a net-zero future requires access to affordable, reliable, sustainable, and modern energy for all (United Nations, 2021). Therefore, countries around the world subsidize electricity resulting in many desirable but also undesirable outcomes (Lay et al., 2013; Shahbaz et al., 2017; Balarama et al., 2020; Imelda, 2020). While many studies focused on the consequences of subsidizing electricity, little research has focused on how it affects health and changes the preference for electricity consumption. In this article, we discuss this issue by providing evidence that subsidizing electricity not only helps reduce pollution and thus improve health outcomes but also changes household preferences for electricity. Using the case of electricity subsidy in Ulaanbaatar, Mongolia, we document that the provision of electricity subsidy is associated with significant changes in electricity expenditure even when it is not subsidized. We subsequently explore potential mechanisms and conclude that change in preference is the most plausible explanation.

We study the case of electricity subsidy in Ulaanbaatar, as it presents three valuable features for our purposes. First, the winter in Mongolia is very cold, with the temperature falling up to -30^{o}C at night. Such low nighttime temperature implies that people can be severely unwell if they cannot heat their homes. This is particularly problematic for the people living in traditional "ger" (a form of a tent), which is known to be energy-inefficient (MEEI, 2020). Second, as a developing country, Mongolia has many low-income households living below or close to the poverty line (NSO, 2020). Extreme cold forces them to use dirty energy like coal to warm their home during winters. Harmful chemicals and particulate matter from the use of coal cause indoor pollution, which is so severe that it also causes severe outdoor pollution at the regional level (Markandya and Wilkinson, 2007; Haines et al., 2007). Both indoor and outdoor pollution results in poor health of the members of the affected households.

Third, the subsidy rate on electricity consumption for eligible households in Ulaanbaatar is huge, ranging from 50–100 percent during cold winter months from October to April. With the aim to reduce fine particulate matters and other airborne toxins that result from the residential use of coal for cooking and heating during cold winter months, the subsidy has been in place since 2011. Thus the subsidy is expected to bring significant health benefits to the eligible residents who suffer substantially from respiratory and other related illnesses. The subsidy is expected to benefit the ineligible population as they are also exposed to reduced outdoor pollution caused by the eligible households. The significant price subsidy can also alter the recipient households' preference and thus electricity consumption pattern in the short and long run.

The results of this article highlight how a subsidy to clean energy like electricity can achieve the intended health outcomes and change the preference for energy in a context where people burn dirty fuels like coal and wood for heating homes and cooking. The economic literature has paid little attention to these channels, despite the existing evidence linking air pollution to morbidity and mortality (Neidell, 2004; Currie et al., 2009a,b) and product use to habit formation and behavioral change (Jessoe and Rapson, 2014; Meriggi et al., 2021). Instead, it has mostly focused on the effect of electricity subsidy on welfare (Giuliano et al., 2020; Hahn and Metcalfe, 2021; Alvarez and Tol, 2021), energy demand (Burke and Kurniawati, 2018; Durmaz et al., 2020), energy conservation (Allcott and Rogers, 2014; Ito, 2015; Boccard and Gautier, 2021) and lost opportunities (Davis, 2014; Plante, 2014; Coady et al., 2019). Identifying and quantifying the intended and unintended consequences is important to inform the debate on energy policies and to compare the net benefits with the cost of the subsidy.

To empirically identify the effect of the subsidy on the probability of reporting illness and the expenditure on electricity, we employ Mongolian microdata. The five rounds of nationally representative Mongolia Household Socio-Economic Survey (HSES) data allow us to model individual illness and electricity expenditure on the eligibility of the subsidy. The detailed information in the survey enables us to control for many socioeconomic, locational, and demographic factors and improve the precision of the estimated impacts.

The main challenge in identifying the impact is that households eligible for subsidy are systematically different from those not eligible. To overcome this concern, we use a difference-in-differences (DiD) approach exploiting two sources of variation: the eligibility of the subsidy and changes in the provision of subsidy over the years, particularly between 2010 and 2012. Since the subsidy has been given to households living in houses and 'gers' in specific regions for particular years, it provides us with a perfect quasi-natural experimental situation. The setup allows us to employ a DiD technique and produce credible estimates of the impact of subsidy. The main identification assumption is that the change in electricity expenditure over time for both types of households would be similar in the absence of the subsidy.

We believe that, conditional on satisfying the common trend assumption, the difference-in-differences method is the best approach to evaluate a large electricity subsidy with a sufficiently large sample size. A randomized control trial (RCT) research design for investigating the impact of electricity subsidy is rare due to the huge cost involvement and ethical issues. Moreover, RCTs in such situations are likely to perform poorly due to the possibility of bias in selecting the sites (Allcott, 2015).

We find that electricity subsidy effectively reduces illness, including respiratory diseases. Our estimates suggest that the electricity subsidy reduces the reported illness by 5-6 percentage points (pp) except for 2016 when the subsidy-eligible households badly suffer from the spread of infectious diseases. The reduction is about 3-5 pp when we consider only respiratory illness. While the lack of appropriate data does not allow us to compare the pollution level between the subsidy-eligible and ineligible regions with a credible econometric method and directly verify the effectiveness of the subsidy, our results provide indirect evidence in favor of the policy effectiveness.

Having established that electricity subsidy is associated with a reduction in pollution-induced illness, we look for the change in the expenditure pattern on electricity.[1] We find that eligible households increase their electricity expenditure both in winter and non-winter seasons. In particular, the subsidy increases electricity expenditure by 17–24 percent in winter months and 16–23 percent in non-winter months. The results are robust to the sample restrictions, alternative estimation methods, and model specifications. We also find evidence of the presence of common trends in all cases. It is important to note that our results refer to the total expenditure on electricity, which includes the heavily discounted expenditure (a 50-100% discount, depending on the month and year)[2].

Increasing access to clean fuel and reducing energy poverty through subsidies have significant public health benefits. The transition from fossil fuel to electricity significantly improves indoor and

[1]Consumption is a more important policy variable than expenditure. Since we do not have data on consumption, we analyze expenditure on electricity. However, when it is not apparent, we explained the implication of our findings on electricity consumption. Using available information, we also provide a back-of-the-envelope calculation of overtime consumption of people eligible for subsidy against those who are not.

[2]For example, in periods when the discount is 100% in winter months (October-April), households would need to *more than double* their consumption of electricity (in kWh) for their observed nominal electricity expenditure to increase.

outdoor air quality. Air pollution is the leading cause of morbidity for infants and children (Neidell, 2004; Currie et al., 2009a,b). Furthermore, being unable to afford the electricity to heat homes at a comfortable level has adverse impacts on mental well-being and self-assessed health conditions (Churchill et al., 2020; Llorca et al., 2020), infant health (Cesur et al., 2017; Palma et al., 2022) and mortality during winter months (Neidell et al., 2021). Changes in preference to switch to clean energy are thus an added benefit of the subsidy program, which can have a protective impact on human health and the environment. Thus, the electricity subsidy can be an essential policy intervention in developing countries where people rely heavily on biomass and fossil fuel for heating and cooking, which have adverse health impacts.

Our study adds to the growing literature on the impact of an electricity subsidy on improving health outcomes in developing countries and the literature on habit formation for clean energy use. A limited study investigates the impact of a large electricity subsidy in a developing country context (e.g., Burke and Kurniawati, 2018; Khalid and Salman, 2020). Using a quasi-experiment setting with rich microdata, we provide credible estimates of the effect of the subsidy on illness and electricity expenditure. Our findings of increased electricity use resulting from a large electricity subsidy are particularly novel that can shape public policies related to poverty, energy, and the environment.

The rest of the paper proceeds as follows. Section 2 presents some background of Mongolia and the context of the policy that we examine in this study. Methodology and data employed for our investigation are discussed in Section 3. Section 4 presents the results and discusses the validity of the identifying assumption and the robustness of the results. It also discusses the policy implications of our study. Section 5 concludes the paper.

2. Background

2.1. Coal use and public health concerns in Mongolia

Ulaanbaatar, the capital city of Mongolia, is one of the coldest capitals, with temperatures fallng significantly during the winter. Such low temperature requires enormous energy demand in the winter for keeping the place of living warm. While around 98 percent of the population in Mongolia has access to electricity, the country's electricity consumption has been 2.3 MWh/capita in 2018, up from 1.05 MWh/capita in 2000 (Ministry of Energy, 2018). It is below the average level (2.8 MWh/capita) in the Asia-Pacific region and is short of meeting the residential demand for heating.[3] Therefore, some of the city's residential energy demand for heating during winter is met by heavy use of coal, creating a deadly level of indoor and outdoor air pollution.

The use of coal by residents for heating in the winter months is the major source of air pollution in Ulaanbaatar. More than 60 percent of households in the city live in traditional Mongolian gers and basic houses with no water, sanitation, and heating infrastructure in the "ger districts."[4] These households burn raw brown coal for cooking and heating during cold winter months from October through April (Allen et al., 2013). About 200,000 households living in ger districts burn around 200,000 tons of raw coal and 160,000 cubic meters of firewood annually to heat their homes (World Bank, 2019). Although ger district households accounted for around 16 percent of total electricity consumption during 2014–2018, their residential heating is met by burning of coal in winter.[5]

Mongolia also heavily depends on coal-based power plants for generating electricity. The country produced 79 percent of its electricity from thermal power plants in 2018 (Ministry of Energy, 2018). Coal-based electricity generation is the largest emitter of carbon dioxide (CO_2) in the country, with CO_2 emissions standing at 6.7 tCO_2 per capita in 2018, which is higher than the average 3.92 tCO_2 per capita in the Asia–Pacific region (IEA, 2018). Both electricity generation and residential use of coal result in high levels of air pollution in all major cities in Mongolia, including Ulaanbaatar.

The burning of fossil fuels releases many toxic substances in the air, ranging from fine particulate matter and nitrogen dioxide (NO_2) to sulfur dioxide (SO_2). Among these pollutants, the most dangerous fine particulate matter of 2.5 microns or less in diameter ($PM_{2.5}$) was 12 times higher than the WHO guideline of 10 $\mu g/m^3$ in 2011 in Ulaanbaatar (Guttikunda et al., 2013). The daily mean $PM_{2.5}$ declined to 86 $\mu g/m^3$ in 2014, reached 164 $\mu g/m^3$ in 2016 and 138 $\mu g/m^3$ in 2018, with the maximum 280 $\mu g/m^3$ in the last year (Ganbat et al., 2020). The $PM_{2.5}$ level has remained consistently higher than the safe level set by the WHO and the national standard of 50 $\mu g/m^3$

[3]MWh represents megawatt-hours of electricity. Six laptop computers can operate in one kWh during a standard workday. tCO_2 here indicates greenhouse gas emissions equivalent to tons of CO_2.

[4]A ger or yurt is a traditional Mongolian house that is built by assembling a wooden framework and covering it with traditional felt. It is the most portable and suitable dwelling for nomads. However, a significant proportion of people still live in gers in both rural and urban areas in Mongolia. In 2016, 40 percent of the total Mongolian population lived in gers, 36 percent in detached houses, and 24 percent in apartments (NSO, 2017).

[5]Households in apartments and public and private entities consumed 11 and 73 percent of total electricity during the same period, respectively.

(IQ Air, 2020). The high level of pollution made Ulaanbaatar the fourth most polluted city in the world in 2020.

Air pollution is the sixth riskiest factor that drives death and disability in Mongolia. The death rate from air pollution was 82 deaths per 100,000 in 2017, which was higher than 79 in the Central Asian region (IHME, 2018). Diseases of the respiratory system were the leading cause of morbidity among children and adolescents in 2018, with 4,755 cases per 10,000 population for the age group 1–4. Pneumonia was the most frequently occurring disease among infants and children under-five and accounted for 28 percent of morbidity in 2018 (NCHD, 2018). Outdoor air pollution contributed to 29 percent of cardiopulmonary deaths and 40 percent of lung cancer deaths in the capital city, all of which accounted for 10 percent of total mortality (Allen et al., 2013). All of these indicate that Mongolia faces significant challenges to meet its current and future need of clean energy and mitigate the negative health impacts of coal-based power generation and the burning of coal for residential heating, especially in its capital city.

2.2. Mongolian Government's policies to curb pollution

Although air pollution reduction in the capital city has been among the top priorities of the Government of Mongolia (GoM), the desired outcomes of the policies implemented have not materialised. The Parliament passed the Law on Air Pollution Reduction in 2011, and the GoM has put relevant policies in place to implement the law. The first significant project implemented to reduce air pollution was the Ulaanbaatar Clean Air Project (UBCAP), implemented by the GoM and the World Bank in 2012–2019, with total financing of US$27m. The project distributed around 40,000 clean stoves to ger district households in the initial stage, 2013–2015. Between 2010 and 2015, the project distributed a total of 175,000 clean stoves to ger district households with subsidies from the Ministry of Energy, the City of Ulaanbaatar, the Millennium Challenge Corporation, and UBCAP (World Bank, 2019). However, the initiative of the project has been inadequate to address air pollution effectively in the country.

Although there are three coal-fired thermal power plants are located adjacent to the city, the primary pollution source is the combustion of coal by residents to heat their homes in winter (ERC, 2020). Thus, the extent of air pollution reduction depends mainly on making households switch from coal-based heating to alternative energy sources such as electricity. The GoM has been providing subsidies through discounts for nighttime use of electricity for ger district households at various discount rates since 2011. The Ministry of Environment and Green Development (MoEGD) and the Ulaanbaatar City Mayor's Office jointly identify the air pollution reduction zones where households burn raw coal in winter. The households in these zones are eligible for the nighttime use electricity discounts that the Energy Regulatory Commission sets.

The timelines of subsidy provisions and zoning details are provided in Table 1. Panel A lists the evolution of the subsidy chronologically. The first discount was a 50 percent reduction for nighttime use of electricity during the winter months from October until May, effective from November 2011 to December 2016.[6] Then the subsidy was increased to 100 percent discount for nighttime use in 2016, and a time limit was set from 9 pm–6 am in 2017.[7] The GoM put a cap on the discount for nighttime electricity use in October 2018, limiting it to 700kWh and 1,500 kWh for 220V and 380V capacity, respectively. The GoM extended the subsidy to the national level in 2019 with the provision of 50 percent discount for the nighttime rate to ger district households in province centers and settlements with a population above 10,000 (ERC, 2019).

The subsidy applies to only households living in the ger districts classified into specific zones. Panel B of Table 1 lists the changes in the details of the zones. The earliest data on the zoning is reported in 2015. Although the zoning changes every year, we believe that it has not changed significantly. Initially, there were two polluting zones and one affected zone, with total three zones identified in 2015. In 2017, one of the polluting zones was divided into two, resulting in three polluting zones and one affected zone (MoEGD, 2015, 2017).

Zones vary by population, type of residence and pollution level. Zone 1 is the primary source of air pollution, shown in light grey in the districts of Songinokhairkhan, Chingeltei, Sukhbaatar, and Bayanzurkh in Figure 1, where 130,076 households live and $PM_{2.5}$ concentration was 10–30 times higher than the national standard of 50 $\mu g/m^3$ in 2017. Zone 2, shown in dark grey in the districts of Songinokhairkhan, Khan-Uul, and Bayanzurkh in Figure 1, where 51,910 households live and $PM_{2.5}$ concentration was 3–8 times higher than the national standard. Zone 3, shown in

[6] We have not been able to acquire aggregate data on the amount of subsidy provided and the number of participants households prior to 2017.

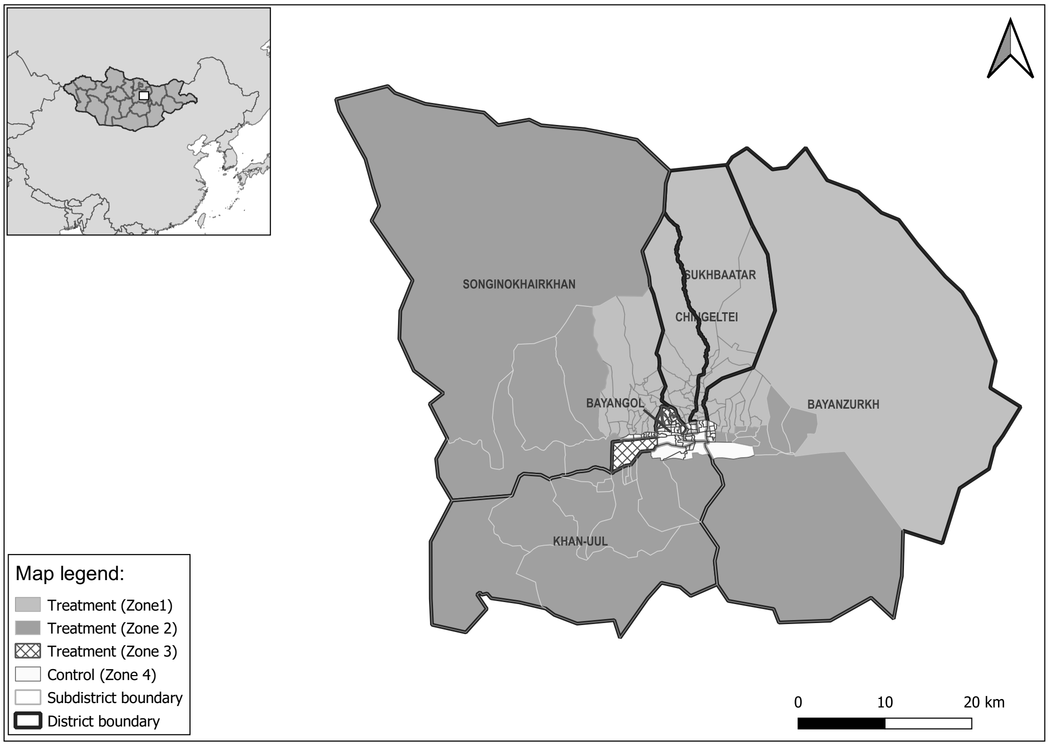
[7] There are two types of tariffs for residential electricity consumption. A kWh of electricity is priced at US$0.041 for the first 150 kWh, and US$0.049 for over 150 kWh per month for simple meters. A double meter tariff is also applied separately for daytime and nighttime use. The daytime tariff (6 am–9 pm) is US$0.043 per kWh, while the nighttime tariff (9 pm–6 am) is US$0.032 per kWh. The monthly base tariff is US$0.828 per kWh (Ministry of Energy, 2018).

Table 1: **Overview of electricity subsidy programs and zoning policies**

Date	Policy name	Duration	Actions
Panel A: Electricity subsidy programs			
10 Feb 2011	Parliament Resolution No.11 to implement the Law on Air Pollution Reduction	1 October–1 May	Specified electricity subsidy program for air polluting zones.
2 Nov 2011	Government Resolution No.309 on air pollution reduction and electricity tariff discount	1 October–1 May	50% discount for the evening and night rates for households in the air pollution reduction zones.
17 Jul 2014	Joint Resolution No.263/A-616 of Minister of Environment and Green Development and Ulaanbaatar City Mayor	1 Oct 2014–1 May 2015	50% discount for the evening and night rates for households in the air pollution reduction zones.
28 Dec 2016	Government Resolution No.214 on air pollution reduction and electricity tariff discount	28 Dec 2016–1 May 2017	100% discount for households in the air pollution reduction zones in the capital city. Zones 1, 3 and 4 remain.
4 Jul 2017	Government Resolution No.199 on air pollution reduction and electricity tariff discount	1 Oct 2017–1 May 2018	100% discount for households from 9 pm to 6 am in the air pollution reduction zones in the capital city. Zones 1, 2, 3 and 4 remain.
25 Oct 2018	Energy Regulatory Commission Resolution on discount for night tariff rates	1 Nov 2018–1 Apr 2019	100% for 700kWh for 220V capacity; 100% for 1500 kWh for 380V capacity; 50% discount on the excess from 9 pm to 6 am. Zones 1, 2, 3 and 4 remain.
Panel B: Policies on zoning			
23 Dec 2015	Joint Resolution No.A989 of Minister of Environment and Green Development and Ulaanbaatar City Mayor	23 Dec 2015–10 Jan 2017	Zones 1, 2 and 3 are identified and the 50% discount applies from the 2014 Government Resolution No.263/A-616.
10 Jan 2017	Joint Resolution No.A014/-A/19 of Minister of Environment and Green Development and Ulaanbaatar City Mayor	10 Jan 2017–6 Jul 2018	Zones are modified. Zones 1, 2, 3 and 4 are identified and the 100% discount applies from the 2016 Government Resolution No.214. and 2017 Government Resolution No.199.
6 Jul 2018	Joint Resolution No.A/226-A/619 of Minister of Environment and Green Development and Ulaanbaatar City Mayor	1 Nov 2018–1 Apr 2019	Zones 1, 2, 3 and 4 are modified slightly and the 100% discount applies from the 2018 Energy Regulatory Commission Regulation.

Source: Unified Legal Information System (2021)

hashed pattern in Figure 1, where 12,446 households live and $PM_{2.5}$ concentration was 2–5 times higher than the standard. Both zones 2 and 3 are affected by the air pollution from Zone 1. Lastly, Zone 4, in white in Figure 1, is affected by air pollution from zones 1, 2, and 3, and all households in Zone 4 live in modern apartments connected to a central heating system. The $PM_{2.5}$ concentration in Zone 4 was 2–3 times higher than the national standard (NSO, 2021).



Source: Compiled by authors

Figure 1: Ulaanbaatar city district zoning map for air pollution reduction

The eligibility criteria for households to receive the subsidy are straightforward. A household must reside in zones 1, 2, and 3 and have one of the heating solutions such as electric and gas heaters, renewable energy-based heating, or clean stoves that use only coking or processed clean coal as described in the Law on Air Pollution Reduction (PoM, 2011). In addition, a household must have no outstanding electricity bills, have both day and nighttime use meters, and ensure the safe installation of electric wires, switches, and plugs (MoEGD, 2015).

The subsidy program had a wide coverage rate and benefited a significant proportion of people. There were 365,000 residential electricity consumers in Ulaanbaatar in 2018, and 152,000 of those households live in the ger districts eligible for the subsidy. Eighty-five percent of ger district households had both daytime and nighttime meters for electricity consumption, making them eligible for the subsidy (Bold, 2018). The total subsidy amount was US$2.5m in 2017 and US$3.6m in 2018.

The households were estimated to reach 116,000 with the subsidy amount of US$7.4m in 2019, including those households in provinces (ERC, 2019). The average electricity consumption for ger district households was 458kWh in 2019, with eligible households receiving subsidies ranging from US$15–30 per month during the winter months (Tsetseg, 2020).

Theoretically, the electricity subsidy will have both income and substitution effects for the participating households. We illustrate the mechanisms through which households would adjust their consumption behaviour in Figure 2. The horizontal axis denotes electricity consumption (x_1) and the vertical axis denotes the consumption of non-electricity goods (x_2). A participating household's budget constraint and indifference curves are B_1 and I_1, respectively, with the equilibrium consumption bundle of x_2^1 units of non-electricity goods and x_1^1 units of electricity.

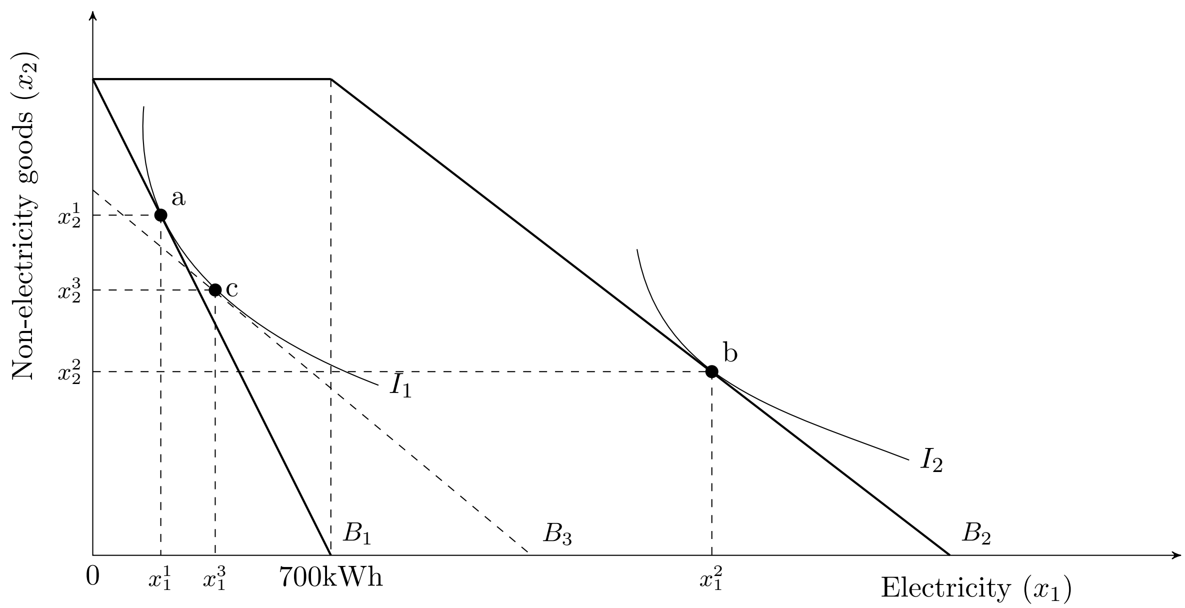


Figure 2: **Impact of an electricity subsidy**

With the electricity subsidy, households consume up to 700kWh of free electricity at night and 50 percent discount thereafter, shifting the budget constraint to B_2. With indifference curve I_2 the new equilibrium occurs at point b with consumption bundle (x_1^2, x_2^2). To isolate the income and substitution effect, we draw the budget line B_3 that is parallel to B_2 and tangent to the original indifference curve I_1. Movement from point a to c indicates the substitution effect that raises electricity consumption by $x_1^1x_1^3$. On the other hand, movement from point c to b indicates the income effect that raises electricity consumption by $x_1^3x_1^2$. The figure demonstrates that a large subsidy results in a significant increase in the electricity consumption by the beneficiary households. With an average consumption (of subsidised and un-subsidised households) below 700kWh implies that households may experience a corner solution, at the kink at the end of the horizontal part of B_2, rather than the optimum shown in the figure[8].

The figure indicates that it is theoretically obvious that we should expect an increase in electricity consumption by treated households. What is less clear is the effect of the subsidy on the *nominal* electricity expenditure, as this depends on both the elasticity of the demand for electricity, and on any change in behaviour in the summer months when heating is not needed. Given the significant decline in the effective average annual price of the electricity for the treatment households (in the range of 50-100% in the winter months), and the fact that households do not need to use heating to any meaningful degree in the summer months, our finding that the nominal expenditure on electricity increases significantly indicates a long-term change in household behaviour as they purchase electric appliances.

3. Data and methodology

3.1. Household survey data

We use the data from the most recent five rounds of the Mongolia Household Socio-Economic Survey (HSES), a nationally representative cross-sectional household survey undertaken by the National Statistics Office of Mongolia every two years. The survey uses a stratified two-stage sample design based on population figures obtained from local governments' administrative records. The first stage stratifies the capital city, Ulaanbaatar, and the 21 provinces. The second stage divides the 21 provinces into two substrata: urban, comprising the provincial capitals, and rural, consisting of small towns and the countryside (NSO, 2018).[9] We focused our analysis on households in the capital city Ulaanbaatar, where the electricity subsidy program initially commenced in late 2011.

[8] The electricity price subsidy reduces the average price for the participating households during the winter months. Since the subsidy evolved and became more generous, households adjusted their consumption behaviour. For example, the average nighttime electricity consumption being much lower than 700kWh indicates that households, on average, do not pay for nighttime electricity consumption. Therefore, any expenditure on electricity for the treatment households comes from their daytime electricity consumption.

[9] The HSES questionnaires and the primary datasets are publicly available from the NSO Census and Survey data catalog http://web.nso.mn/nada.

The program has been extended to other provinces in 2019, after that no HSES data are available till now.

The five rounds of the HSES - 2010, 2012, 2014, 2016, and 2018 - include 73,088 households. We shelved 55,211 households in the provinces and 960 households in the districts that did not participate in the subsidy program. We then dropped 2,584 households belonging to neither the control nor the treatment groups, as described in Subsection 3.2 below. We eliminated a further 467 households that do not meet the requirements to receive the subsidy, such as student dormitories, public houses for employees, non-living quarters, and other types of properties. Finally, we omitted 125 households as they did not report any expenditures on food or electricity. This gives us an analysis sample of 13,741 households in Ulaanbaatar consisting of 51,798 individuals. Of them, 21,985 individuals in 5,766 households have been surveyed in winter months while information of the rest 29,813 persons in 7,975 households have been collected during the non-winter months.

The HSES records whether, in the last month before the survey, a person's has been ill and, if yes, whether the illness is related to the respiratory system. Panel A of Table 2 presents the overall illness rates in winter months, separately for the treatment and control individuals.[10] The general illness level is higher for the treatment individuals than their control counterparts in 2010. However, the control group's illness level increases over time at a higher rate than the treatment group. A similar pattern is observed for respiratory system illness.

Panel B of the table reports the illness rates in non-winter months. Unlike the winter months, treatment individuals report a slightly higher level of illness than the control individuals in 2014-2018. In contrast, the respiratory illness rates are a bit higher for the treatment group in 2010 and 2018. Overall, the treatment individuals report a higher level of illness in non-winter months, whereas the control group reports more in winter.

The survey also records expenditure on energy and electricity that we also investigate to examine the impact of the subsidy. Panel C in Table 2 presents the summary statistics for the outcome variables in winter months.[11] The monthly household electricity expenditure was lower for the treatment households than their control counterparts in the base year, 2010.

[10] We recorded 1,012 individuals with missing illness data as not being ill since coding zeros as missing is common in survey data.

[11] In our analysis sample, we replaced the missing monthly electricity expenditures of 32 households with their annual electricity expenditures averaged over 12 months.

Table 2: **Summary statistics of dependent variables**

	2010		2012		2014		2016		2018	
Variable	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control
Panel A: Individual illness in winter months										
Sick in the past month	0.09	0.06	0.07	0.10	0.07	0.10	0.11	0.08	0.11	0.13
	(0.28)	(0.24)	(0.26)	(0.30)	(0.26)	(0.30)	(0.31)	(0.27)	(0.31)	(0.34)
Respiratory illness	0.04	0.02	0.04	0.04	0.04	0.06	0.07	0.04	0.04	0.07
	(0.19)	(0.15)	(0.19)	(0.20)	(0.19)	(0.24)	(0.25)	(0.20)	(0.21)	(0.25)
Number of individuals	2,203	1,306	3,266	1,508	2,996	1,305	3,117	1,474	3,069	1,741
Panel B: Individual illness in non-winter months										
Sick in the past month	0.05	0.05	0.06	0.07	0.07	0.05	0.07	0.06	0.10	0.07
	(0.23)	(0.22)	(0.24)	(0.25)	(0.25)	(0.21)	(0.25)	(0.24)	(0.30)	(0.25)
Respiratory illness	0.02	0.01	0.02	0.03	0.02	0.02	0.02	0.03	0.03	0.01
	(0.12)	(0.11)	(0.14)	(0.17)	(0.14)	(0.14)	(0.15)	(0.16)	(0.17)	(0.12)
Number of individuals	2,979	1,949	4,133	2,456	4,369	1,948	4,227	1,687	4,352	1,713
Panel C: Household energy expenditures in winter months										
Electricity expenses	12.47	15.85	14.14	15.62	13.56	13.88	15.31	16.41	15.64	15.10
	(7.53)	(6.65)	(9.68)	(8.55)	(10.99)	(6.17)	(10.78)	(6.36)	(12.18)	(5.52)
Share of electricity expenses (%)	2.99	2.69	2.78	2.19	2.66	1.90	3.39	2.73	3.40	2.38
	(1.62)	(1.32)	(1.76)	(1.43)	(1.85)	(1.16)	(2.11)	(1.36)	(2.44)	(1.37)
Other energy expenses	29.25	0.07	50.02	0.16	34.87	0.07	28.28	0.02	27.04	0.03
	(31.81)	(1.18)	(55.90)	(2.04)	(35.19)	(1.00)	(29.88)	(0.37)	(25.74)	(0.51)
Share of other energy expenses (%)	7.05	0.00	10.12	0.03	7.63	0.01	6.63	0.00	6.35	0.00
	(7.65)	(0.03)	(12.23)	(0.34)	(9.16)	(0.10)	(7.69)	(0.06)	(7.24)	(0.04)
Number of households	528	353	797	424	798	387	802	424	758	495
Panel D: Household energy expenditures in non-winter months										
Electricity expenses	13.91	15.96	14.74	15.91	13.70	13.69	15.28	15.71	16.96	14.70
	(9.32)	(6.10)	(8.31)	(6.74)	(11.65)	(5.36)	(9.18)	(5.64)	(12.82)	(4.71)
Share of electricity expenses (%)	3.18	2.90	2.94	2.18	2.60	1.85	3.56	2.78	3.49	2.35
	(1.83)	(1.71)	(2.17)	(1.53)	(1.78)	(0.97)	(1.91)	(2.16)	(2.33)	(1.30)
Other energy expenses	15.69	0.07	19.75	0.13	11.11	0.12	16.04	0.02	11.73	0.04
	(35.44)	(1.05)	(39.14)	(1.43)	(27.93)	(1.53)	(32.95)	(0.36)	(22.52)	(0.90)
Share of other energy expenses (%)	3.92	0.01	3.86	0.02	2.25	0.01	3.87	0.00	2.62	0.01
	(9.12)	(0.22)	(8.10)	(0.24)	(6.47)	(0.17)	(8.00)	(0.04)	(5.97)	(0.13)
Number of households	718	544	1,048	711	1,155	587	1,133	505	1,089	485

Notes: Treatment households are those living in gers and basic houses in zones 1, 2 and 3. The control households are those living in apartments in zone 4. Means are reported in thousand Tugrik (MNT). The exchange rate for the end of survey period (December) ranged from US\$1 ≈ 1,257.0 MNT in 2010 to US\$1≈ 2,647.0 MNT in 2018. All values are on per capita monthly basis and adjusted for inflation. Standard deviations are reported in the parentheses.

The treatment group increased its electricity expenditures in 2012, decreased them in 2014, and increased them later. Conversely, the control households' electricity expenditures remained stable over the years, except in 2014 when both groups had lower expenditures than in the previous year. In the table, we have also presented the share of electricity expenditures in household total expenditures. The expenditure share of electricity was three percent for the treatment households in 2010, whereas it was slightly lower for the control counterparts. The share declined for the treatment households in 2012-2014 and increased in 2016-2018. In contrast, the control households had a more stable share of electricity expenditures in all years, except in 2014 when it was much lower than the other years.

The non-electricity energy expenditure displays a downward trend for the treatment households as they are burning less coal and wood at night due to the subsidy. Since the control households have central heating, their other energy expenditures are minimal compared to the treatment group. The treatment households' share of non-electricity energy expenditures in household total expenses is seven percent in 2010, and it increases to above ten percent in 2012 and declines after that. Overall, the share of energy expenditures in total household expenses declines slightly for the treatment households. However, we observe that the treatment households increase their electricity expenditures more than the control group during the analysis period.

Panel D of Table 2 shows the energy expenditures in non-winter months. Both electricity and other energy expenditures follow similar patterns as in the winter months. However, the share of electricity expenditures in total expenditures is higher for the treatment households in non-winter months than in winter as there is no subsidy in the former period. In contrast, their share of non-electricity energy expenditures is lower in that season as they burn wood and coal mainly for cooking and less for heating purposes in non-winter months.

One advantage of using HSES for our investigation is that it collects some additional information on the socio-demographic characteristics of the participants that are important to control for in the analysis. Employed household member-specific information includes age, gender, education, marital status, employment, income and type of residence. On the other hand, collected household-specific information includes the household's residential property type, income and expenditure. In both types of models, we also include the type of heating devices used in residence to control for the channel that public distribution of heating devices can affect household consumption of electricity and thus their members' illness level.

Panel A in Table 3 reports the summary statistics of the control variables for the individual-level analysis. The treatment individuals appear to be younger, have lower years of education, and have a larger family. For both groups, about half of the sample is female, and around 40 percent of them live in traditional gers. There is no difference in the consumption expenditure between the two groups. The share of treatment individuals who use private boiler heaters increases over time while there is no clear pattern in electric heaters. Finally, the percentage of treatment individuals using traditional stoves reduces over time. This indicates that the treatment households switch from coal-based heating to cleaner solutions such as private boilers. Panel B in the table reports the summary statistics of the control variables for our household-level analysis. It shows that the age, gender, and marital status of household heads are similar for both groups, and they remain similar throughout the periods. Treatment household heads have slightly lower education and income and have larger families than the control group.

3.2. Empirical model

Our data will allow us to employ a flexible difference-in-differences (DiD) model to evaluate the impact of the subsidy program on household electricity expenditures. The specific model is outlined below

$$y_i = \alpha + \beta d_z + \sum_{t=2012}^{2018} (\gamma_t d_t + \delta_t d_z \times d_t) + \mathbf{X_{it}}\boldsymbol{\theta} + \phi_z + \varepsilon_i \tag{1}$$

where, for each individual (or household in other models) i, y represents the likelihood of reporting illness (or the natural logarithm of household monthly electricity expenditure in other models), d_z is a dummy variable taking the value of one for the treatment group who live in the air pollution reduction zones 1, 2 and 3 (the light and dark grey, and hashed patterns areas in Figure 1) where the electricity subsidy is provided during winter, and zero for the control households who live in zone 4 (white areas in Figure 1), d_t is a dummy taking the value of one for the year t and zero for other years (2010 is the reference period), $\mathbf{X}$ is a set of control variables and ε accounts for

Table 3: **Summary statistics of control variables for winter month sample**

	2010		2012		2014		2016		2018	
Variable	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control
Panel A: Individual level controls										
Individual's age (years)	28.2	31.6	28.4	30.5	29.0	30.3	28.7	29.1	28.0	30.6
	(18.5)	(19.9)	(18.8)	(19.8)	(19.3)	(19.5)	(19.6)	(20.0)	(20.1)	(21.6)
Individual is female	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)
Individual's education (years)	9.0	10.2	8.9	10.7	8.8	10.3	8.7	9.9	8.6	10.2
	(5.4)	(5.9)	(5.9)	(7.0)	(5.6)	(6.4)	(5.8)	(6.5)	(5.9)	(6.7)
Household size	5.0	4.3	4.9	4.2	4.4	3.9	4.6	4.1	4.9	4.3
	(2.4)	(1.6)	(2.2)	(1.6)	(1.6)	(1.3)	(1.7)	(1.4)	(2.0)	(1.6)
Ln(consumption)	13.1	13.2	13.4	13.5	13.4	13.5	13.2	13.3	13.3	13.4
	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)
Lives in ger	0.4	0.0	0.4	0.0	0.4	0.0	0.4	0.0	0.4	0.0
	(0.5)	(0.0)	(0.5)	(0.0)	(0.5)	(0.0)	(0.5)	(0.0)	(0.5)	(0.0)
Private boiler	0.02	0.00	0.09	0.00	0.11	0.00	0.11	0.00	0.13	0.00
	(0.1)	(0.0)	(0.3)	(0.0)	(0.3)	(0.0)	(0.3)	(0.0)	(0.3)	(0.0)
Electric heater	0.00	0.00	0.01	0.00	0.03	0.00	0.01	0.00	0.03	0.00
	(0.0)	(0.0)	(0.1)	(0.0)	(0.2)	(0.0)	(0.1)	(0.0)	(0.2)	(0.0)
Traditional stove	0.96	0.00	0.89	0.00	0.88	0.00	0.89	0.00	0.87	0.00
	(0.2)	(0.0)	(0.3)	(0.0)	(0.3)	(0.0)	(0.3)	(0.0)	(0.3)	(0.0)
Number of individuals	2,203	1,306	3,266	1,508	2,996	1,305	3,117	1,474	3,069	1,741
Panel B: Household level controls										
Household head's age (years)	45.8	47.7	44.9	45.9	46.2	44.7	46.5	43.9	47.6	47.5
	(13.9)	(14.9)	(14.2)	(15.4)	(14.0)	(14.6)	(13.4)	(14.6)	(13.7)	(15.5)
Household head is female	0.3	0.3	0.2	0.3	0.3	0.2	0.3	0.3	0.3	0.3
	(0.4)	(0.5)	(0.4)	(0.4)	(0.4)	(0.4)	(0.4)	(0.5)	(0.5)	(0.4)
Household head's education (years)	12.0	13.8	12.1	15.3	12.7	15.9	12.5	14.4	12.5	14.7
	(2.5)	(2.4)	(3.4)	(3.3)	(2.9)	(3.0)	(2.5)	(2.1)	(2.5)	(2.3)
Household head is married	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)
Share of working members	0.3	0.3	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.4
	(0.2)	(0.3)	(0.2)	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.2)	(0.3)
Household size	4.2	3.7	4.1	3.6	3.8	3.4	3.9	3.5	4.0	3.5
	(1.9)	(1.6)	(1.8)	(1.5)	(1.6)	(1.4)	(1.6)	(1.5)	(1.8)	(1.6)
Ln(income)	12.3	12.4	13.0	13.5	13.2	13.7	13.3	13.6	13.2	13.7
	(1.2)	(1.5)	(0.7)	(0.8)	(0.6)	(0.6)	(0.5)	(0.6)	(0.6)	(0.6)
Lives in ger	0.4	0.0	0.4	0.0	0.4	0.0	0.4	0.0	0.4	0.0
	(0.5)	(0.0)	(0.5)	(0.0)	(0.5)	(0.0)	(0.5)	(0.0)	(0.5)	(0.0)
Private boiler	0.01	0.00	0.07	0.00	0.10	0.00	0.11	0.00	0.12	0.00
	(0.1)	(0.0)	(0.3)	(0.0)	(0.3)	(0.0)	(0.3)	(0.0)	(0.3)	(0.0)
Electric heater	0.00	0.00	0.01	0.00	0.03	0.00	0.02	0.00	0.03	0.00
	(0.0)	(0.0)	(0.1)	(0.0)	(0.2)	(0.0)	(0.1)	(0.0)	(0.2)	(0.0)
Traditional stove	0.97	0.00	0.90	0.00	0.89	0.00	0.89	0.00	0.88	0.00
	(0.2)	(0.0)	(0.3)	(0.0)	(0.3)	(0.0)	(0.3)	(0.0)	(0.3)	(0.0)
Number of households	528	353	797	424	798	387	802	424	758	495

Notes: Treatment households are those living in gers and basic houses in zones 1, 2 and 3. The control households are those living in apartments in zone 4. Means are reported in thousand Tugrik (MNT). The exchange rate for the end of survey period (December) was US$1 ≈ MNT1,257.0 in 2010. All values are on monthly basis and adjusted for 2010 price level. Standard deviations are reported in the parentheses.

unobservable effects. Please note that we do not have the zoning information for 2012, and so we use the property types and heating source as the main criteria to identify the treatment households.

For individual-level analysis, **X** includes individual-specific controls listed in panel A of Table 3 while for the analysis of electricity expenditure, **X** includes household-specific variables listed in panel B of the same table. We also control for districts, survey years, and months fixed effects to account for district-level and time-specific variations in electricity expenditures. We cluster the standard errors at the household level for the individual-level analysis, and at the district level for the household-level analysis.

The coefficients δ_t in model (1) are the difference-in-differences (DiD) estimates, indicating the impact of the subsidy on the likelihood of reporting illness (or household electricity expenditures). For several reasons, the DiD estimates provide the lower bound of the effect of the subsidy on household electricity expenditure. The first reason is spillover, in which the subsidy also results in reduced pollution for the control individuals. With the increased use of electricity to heat homes, the indoor pollution resulting from burning coal and wood would reduce substantially for the treatment households. This will also result in lower outdoor pollution for the control households, likely reducing their illness level. Second, the use of only a few years of data will ignore the long-run health impact of pollution and thus report lower level of illness.

On the other hand, the electricity expenditures for 2010 include both daytime and nighttime electricity consumption expenditures for the treatment households. However, for the subsidy period 2012-2018, the treatment group's electricity expenditures are more likely to be for daytime usage as the nighttime electricity was effectively free. Thus, the DiD estimates provide the lower bound of the effect of the subsidy on household electricity consumption.

The DiD model compares the difference in the probability of reporting illness (or electricity expenditures) between treatment households (i.e., those receiving the subsidy living in gers and basic houses in the polluting zones) and the control households (i.e., those not eligible for the subsidy living in apartments in zone 4) before and after the policy change. Since households living in apartments in zone 4 are not eligible for the electricity price discount, we have an ideal and clean control group to estimate the program's causal effect.

The identifying assumption for the DiD model is that the difference in the probability of reporting illness and electricity expenditures between the treatment and control households would have remained the same in the absence of the policy. We cannot test the identifying assumption directly. However, we validate the 'common trends' assumption by evaluating the historical trends in electricity expenditures and undertake several placebo tests to examine the impact of the subsidy program (Subsection 4.2).

4. Results and discussion

4.1. Main results

To investigate whether an electricity subsidy program reduces illness and affect household electricity expenditures, we estimate Equation (1) with different sets of independent variables and present those results. In modelling individual illness (or respiratory illness), the first sets of results are derived from a model (basic model) that regresses the dependent variable on treatment and the interaction of treatment and (survey) year dummies, together with district, month, and survey year fixed effects. On the other hand, the final sets of results rely on a model (preferred model) that adds individual-specific controls to the specification, including the heating sources in residence.

In modelling household expenditure on electricity, the first sets of results are derived from a model (basic model) that regresses electricity expenditure on treatment and the interaction of treatment and (survey) year dummies, together with district, month, and survey year fixed effects. The next sets of results rely on a model that adds household-specific controls to the specification, including the heating sources in residence. The final sets of results rely on a model (preferred model) that further adds heating sources in residence. This way of analysis is to ensure that the estimated effects of the subsidy are not driven by any strong association of the treatment variable with any control variable.

The results for the probability of feeling ill in winter seasons are given in Table 4. Column 1 shows the basic model estimates for all ages and indicates that treatment individuals have a three percentage points higher probability of reporting illness in the reference year, 2010. The survey-year fixed effects indicate that the likelihood of feeling unwell increases over time for the control individuals. The likelihood of reporting illness of the treatment individuals, compared to the control individuals, declines by 6.0 and 5.8 percentage points in 2012 and 2014, respectively.

Table 4: **Regression results of DiD models of the probability of illness in winter months**

	All age groups combined		Children (under 14 years)		Working age adults (15-60 years)		Older adults (over 60 years)	
Variable name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	0.030***	0.017	0.050*	-0.017	0.030***	0.033	0.018	0.066
	(0.012)	(0.022)	(0.026)	(0.032)	(0.011)	(0.022)	(0.052)	(0.109)
2012	0.043***	0.082***	0.064**	-0.000	0.041***	0.094***	0.008	0.121**
	(0.012)	(0.017)	(0.028)	(0.045)	(0.012)	(0.015)	(0.048)	(0.057)
2014	0.044***	0.078***	0.102***	0.031	0.035***	0.085***	-0.042	0.059
	(0.013)	(0.017)	(0.030)	(0.045)	(0.013)	(0.015)	(0.051)	(0.057)
2016	0.011	0.022*	0.054**	0.027	-0.003	0.011	0.013	0.039
	(0.011)	(0.012)	(0.026)	(0.027)	(0.010)	(0.010)	(0.055)	(0.055)
2018	0.071***	0.090***	0.105***	0.066**	0.053***	0.079***	0.069	0.130**
	(0.013)	(0.014)	(0.027)	(0.032)	(0.013)	(0.013)	(0.051)	(0.053)
Treatment × 2012	-0.060***	-0.067***	-0.098***	-0.109***	-0.053***	-0.054***	0.002	-0.014
	(0.015)	(0.015)	(0.034)	(0.034)	(0.015)	(0.015)	(0.066)	(0.066)
Treatment × 2014	-0.058***	-0.066***	-0.117***	-0.117***	-0.050***	-0.053***	0.026	0.017
	(0.016)	(0.016)	(0.037)	(0.037)	(0.016)	(0.016)	(0.067)	(0.068)
Treatment × 2016	0.008	-0.000	-0.003	-0.009	0.005	0.002	0.002	0.012
	(0.015)	(0.015)	(0.034)	(0.034)	(0.014)	(0.014)	(0.072)	(0.071)
Treatment × 2018	-0.048***	-0.055***	-0.109***	-0.110***	-0.026	-0.028*	-0.013	-0.020
	(0.016)	(0.016)	(0.034)	(0.034)	(0.017)	(0.017)	(0.069)	(0.069)
Individual's age (years)		0.001***						
		(0.000)						
Individual is female		0.017***		-0.001		0.022***		0.027
		(0.004)		(0.008)		(0.004)		(0.018)
Individual's education (years)		-0.005***		-0.015***		0.003***		0.001
		(0.001)		(0.002)		(0.001)		(0.004)
Household size		0.006*		-0.024**		0.011***		0.031***
		(0.004)		(0.011)		(0.003)		(0.011)
Ln(consumption)		-0.135***		0.249*		-0.211***		-0.386***
		(0.049)		(0.137)		(0.037)		(0.125)
Lives in ger		0.004		0.028**		0.000		-0.035
		(0.006)		(0.012)		(0.006)		(0.028)
Private boiler		0.030		0.093***		0.015		-0.079
		(0.023)		(0.032)		(0.023)		(0.115)
Electric heater		-0.017		-0.097***		0.003		0.178
		(0.023)		(0.031)		(0.030)		(0.120)
Traditional stove		0.013		0.064***		-0.001		-0.040
		(0.020)		(0.024)		(0.020)		(0.104)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.01	0.03	0.02	0.03	0.01	0.02	0.04	0.05
N	21,985	21,985	6,160	6,160	14,233	14,233	1,592	1,592

Notes: Standard errors, clustered at the household level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is individuals living in house, male and using regular heater for residential heating; the reference year is 2010. Columns 1,3,5 and 7 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2,4,6 and 8 add individual–specific controls to the specification, including the type of the residence and heating sources in residence.

The probability of illness changes similarly between the treatment and control individuals in 2016. The insignificant impact of the subsidy in 2016 can be attributable to the outbreak of highly infectious diseases in Ulaanbaatar around that time.[12] The treatment households are likely to have higher risks of contracting infectious diseases because of their housing characteristics and poor hygiene practices which is likely to offset the potential health benefit from the subsidy.

The relative probability of being ill again declines for the treatment individuals in 2018, this time by about 4.8 percentage points. These outcomes are expected as the provision of subsidy allows the treatment households to use electricity for heating and thus benefit directly from the reduced indoor air pollution, although the resulting lower outdoor air pollution will positively affect the health of both the treatment and control individuals.

Results from estimating the preferred model, presented in column 2 of Table 4, shows a similar finding to that of the basic model, but the magnitudes of the DiD coefficients are now slightly higher. We observe that females and older people are more likely to report illness while education and household consumption reduce the likelihood of illness as found previously (Gove, 1984; Winkleby et al., 1992; Ross and Wu, 1996). Housing conditions and heating devices at the residence have no significant effect on illness in our data. Our overall finding is consistent with the previous studies that find a negative effect of pollution on the exposed population (e.g., Janke et al., 2009).

Since distinct age groups may respond differently when they are exposed to pollution, we investigate the impact of the subsidy on the illness level for different age groups. Specifically, we investigate the case for children (under 14 years), working-age adults (15-60 years) and older adults (over 60 years). The DiD estimates for the children, presented in columns 3–4 of Table 4 suggest that the younger benefits significantly from the subsidy. The likelihood of reporting illness for the treatment children, compared to the control children, decline by 10.9 pp in 2012 and 11.7 pp in 2014. Again, it does not decline (relative to the control households) significantly in 2016 but by 11 pp in 2018. The results highlight that air pollution severely affects children, the most vulnerable group and that the electricity subsidy positively impacts their health. This finding is in line with

[12] The outbreak of young children's hand, foot, and mouth diseases was higher than the national average. It had been in its highest record in 2016 since 2010. At the same time, Ulaanbaatar recorded the highest level of measles outbreak in 2016, which was first diagnosed in 2015 after acquiring a measles elimination certificate from the WHO in 2014. (NCHD, 2016, 2018; Orsoo et al., 2019). Hence, the the spread of the infectious disease could have offset the positive health benefits of the electricity subsidy for the treatment households.

other studies which find that air pollution increases infant morbidity and mortality, school absences, and hospital admissions (Neidell, 2004; Currie et al., 2009a; Cesur et al., 2017; Palma et al., 2022).

The results for the working-age population are similar to the analysis for all age groups. Their likelihoods of reporting illness are significantly lower for all years except for 2016. However, the impacts are lower in magnitude for all the years, and it is less significant for 2018. Interestingly, the treatment individuals above the age of 60 do not report significantly higher illness levels than those reported by the control individuals. The pattern is in contrast to Anderson (2020), who find pollution to increase mortality among adults over 75 years of age. The findings for older people in our case may reflect that they have already taken adequate measures for their protection, so the change in air pollution might not immediately impact them.

Air pollution has a direct impact on the respiratory system. Therefore, we investigate next whether the subsidy reduces respiratory illnesses among the population in the winter season. We report the results for all ages, children, the economically active group, and older people in Table 5. The effects are similar to our previous findings with overall illness, but the magnitudes are lower, as expected. For example, compared to their control counterpart, the likelihood of reporting respiratory illness for the treatment individuals has reduced by 3.1, 4.6, and 4.0 percentage points in 2012, 2014, and 2018, respectively (column 2). Again, no significant difference in the changes (in reporting respiratory illness) is observed for all groups for 2016. The results remain similar for children, the working-age population and older adults (columns 4, 6 and 8). This finding is in line with studies that find that air pollution increases respiratory symptoms such as asthma (Chay and Greenstone, 2003; Neidell, 2004).

Overall, the results in Tables 4–5 indicate that the electricity subsidy program significantly reduces the likelihood of reporting illness for all ages, especially the younger children. These short-term gains in health are likely to have significant long-term benefits for the population as healthier residents are generally more productive and will enjoy a higher living standard in the longer run.

Table 5: **Regression results of DiD models of the probability of having respiratory illness in winter months**

	All age groups combined		Children (under 14 years)		Working age adults (15-60 years)		Older adults (over 60 years)	
Variable name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	0.020**	-0.010	0.042*	-0.019	0.014**	-0.003	-0.019	-0.035
	(0.008)	(0.009)	(0.024)	(0.032)	(0.007)	(0.006)	(0.029)	(0.027)
2012	0.023***	0.055***	0.046*	0.075*	0.017***	0.009	-0.009	0.022
	(0.008)	(0.012)	(0.025)	(0.043)	(0.006)	(0.009)	(0.028)	(0.030)
2014	0.040***	0.069***	0.102***	0.126***	0.021***	0.013	-0.007	0.024
	(0.010)	(0.012)	(0.029)	(0.045)	(0.008)	(0.009)	(0.029)	(0.031)
2016	0.016**	0.021***	0.048**	0.047*	0.002	-0.001	-0.011	-0.004
	(0.008)	(0.008)	(0.024)	(0.026)	(0.005)	(0.005)	(0.029)	(0.029)
2018	0.043***	0.058***	0.091***	0.094***	0.024***	0.019**	-0.015	0.001
	(0.009)	(0.010)	(0.025)	(0.030)	(0.008)	(0.008)	(0.026)	(0.026)
Treatment × 2012	-0.029***	-0.031***	-0.072**	-0.074**	-0.018**	-0.018**	0.022	0.025
	(0.011)	(0.011)	(0.032)	(0.031)	(0.009)	(0.009)	(0.035)	(0.034)
Treatment × 2014	-0.045***	-0.046***	-0.106***	-0.101***	-0.027***	-0.028***	-0.011	-0.010
	(0.012)	(0.012)	(0.035)	(0.035)	(0.010)	(0.010)	(0.035)	(0.035)
Treatment × 2016	0.009	0.010	0.012	0.012	0.005	0.004	0.036	0.040
	(0.011)	(0.011)	(0.032)	(0.032)	(0.008)	(0.008)	(0.037)	(0.038)
Treatment × 2018	-0.038***	-0.040***	-0.093***	-0.081***	-0.024**	-0.025**	0.017	0.019
	(0.012)	(0.012)	(0.032)	(0.031)	(0.010)	(0.010)	(0.033)	(0.033)
Individual's age (years)		-0.001***						
		(0.000)						
Individual is female		0.004		-0.003		0.007***		0.009
		(0.003)		(0.008)		(0.002)		(0.009)
Individual's education (years)		-0.002***		0.006**		-0.000		0.003*
		(0.001)		(0.003)		(0.000)		(0.002)
Household size		0.007***		0.005		-0.003		0.008
		(0.002)		(0.011)		(0.002)		(0.005)
Ln(consumption)		-0.123***		-0.130		0.030		-0.125**
		(0.033)		(0.140)		(0.022)		(0.061)
Lives in ger		0.003		0.019		0.001		-0.010
		(0.005)		(0.012)		(0.004)		(0.013)
Private boiler		0.031***		0.063**		0.026***		-0.015
		(0.011)		(0.031)		(0.008)		(0.013)
Electric heater		-0.021		-0.079***		-0.001		0.065
		(0.017)		(0.028)		(0.021)		(0.060)
Traditional stove		0.023***		0.057**		0.018***		0.024**
		(0.006)		(0.025)		(0.003)		(0.012)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.01	0.04	0.02	0.05	0.01	0.01	0.01	0.01
N	21,985	21,985	6,160	6,160	14,233	14,233	1,592	1,592

Notes: Standard errors, clustered at the household level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is individuals living in house, male and using regular heater for residential heating; the reference year is 2010. Columns 1,3,5 and 7 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2,4,6 and 8 add individual–specific controls to the specification, including the type of the residence and heating sources in residence.

Next, we investigate the effect of the subsidy on electricity expenditures, another outcome variable in our study. Again, we conduct separate analyses for expenditures made on winter and non-winter months, and the results are reported in Table 6. The basic model results in column 1 indicate that the electricity expenditure of the treatment households in the winter season are around 34 percent lower in 2010 than those in the control group. The survey year fixed effects indicate that the control households reduced their electricity expenditures in all years, except for 2016. This can be due to the use of energy-saving electric appliances as a result of governmental and non-governmental initiatives for reducing electricity consumption and previous research find that normative social influence can produce change in behaviour (Allcott and Rogers, 2014; Nolan et al., 2008).

The DiD estimates for each survey year are positive and significant, indicating that the treatment households significantly increase their expenditure on electricity relative to their control counterpart. Following the intervention, the difference in electricity expenditures between the two groups declined. Specifically, compared to the control group, the treatment households increased their electricity expenditures by 17, 21, 20 and 30 percent more in 2012, 2014, 2016 and 2018. These estimated effects are particularly large, especially when we consider that they are the lower bound of the estimates, as discussed earlier.

We add household-specific control variables into the model and report the results in column 2 of Table 6. The results are roughly similar except that the estimates of the DiD coefficients are slightly higher than those in the base model. The coefficients of the household-specific control variables, reported in column 2, are intuitive. For example, the household head's age, education, marital status, family size, and household income significantly increase electricity expenditures. Such impacts are expected as they all are likely to affect electricity demand positively.

On the other hand, households with female heads have lower electricity expenditures than those with male heads. Households living in traditional gers have significantly lower electricity expenditures than those living in other residential property types. Households in gers have limited space to heat or use large electrical appliances such as washing machines, refrigerators, and electric cooking stoves compared to houses. This pattern of expenditure has been observed in the previous empirical analysis of electricity demand (Hasan and Mozumder, 2017; Thomas et al., 2020).

Table 6: **Regression results of DiD models of the impact of subsidy on household monthly electricity expenditures**

	Winter months			Non-winter months		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	-0.296**	-0.208**	-0.339**	-0.177***	-0.116***	0.004
	(0.075)	(0.067)	(0.099)	(0.024)	(0.021)	(0.039)
2012	-0.045	-0.125**	-0.113**	-0.034	-0.117**	-0.106**
	(0.038)	(0.032)	(0.032)	(0.033)	(0.035)	(0.035)
2014	-0.133***	-0.225***	-0.209***	-0.161***	-0.246***	-0.232***
	(0.032)	(0.029)	(0.028)	(0.006)	(0.021)	(0.018)
2016	0.043	-0.024	-0.013	-0.006	-0.072	-0.064
	(0.040)	(0.019)	(0.020)	(0.052)	(0.039)	(0.040)
2018	-0.040	-0.127***	-0.115***	-0.073	-0.148***	-0.139***
	(0.030)	(0.014)	(0.012)	(0.037)	(0.017)	(0.017)
Treatment × 2012	0.156***	0.208***	0.185***	0.116	0.180**	0.156*
	(0.034)	(0.047)	(0.041)	(0.060)	(0.058)	(0.066)
Treatment × 2014	0.190**	0.253***	0.193**	0.137**	0.197***	0.161***
	(0.062)	(0.059)	(0.057)	(0.036)	(0.035)	(0.035)
Treatment × 2016	0.186*	0.211**	0.173*	0.132***	0.187***	0.165***
	(0.078)	(0.069)	(0.070)	(0.033)	(0.029)	(0.026)
Treatment × 2018	0.261***	0.298***	0.237***	0.255***	0.294***	0.232***
	(0.058)	(0.057)	(0.048)	(0.031)	(0.030)	(0.032)
Household head's age (years)		0.003**	0.003**		0.002***	0.002***
		(0.001)	(0.001)		(0.000)	(0.000)
Household head is female		-0.001	-0.002		-0.006	-0.008
		(0.017)	(0.019)		(0.014)	(0.015)
Household head's education (years)		0.012***	0.009***		0.012***	0.011***
		(0.001)	(0.002)		(0.001)	(0.001)
Household head is married		0.083***	0.082**		0.078***	0.063***
		(0.019)	(0.024)		(0.011)	(0.013)
Share of working members		0.043**	0.037**		0.021	0.020
		(0.012)	(0.011)		(0.033)	(0.033)
Household size		0.057***	0.060***		0.056***	0.059***
		(0.005)	(0.005)		(0.006)	(0.005)
Ln(income)		0.071***	0.063***		0.069***	0.062***
		(0.013)	(0.012)		(0.012)	(0.011)
Lives in ger		-0.228***	-0.181***		-0.197***	-0.146***
		(0.015)	(0.009)		(0.015)	(0.010)
Private boiler			0.200**			-0.016
			(0.070)			(0.026)
Electric heater			1.504***			1.005***
			(0.104)			(0.101)
Traditional stove			0.109			-0.160**
			(0.066)			(0.041)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.04	0.17	0.26	0.03	0.17	0.27
Number of households	5,766	5,766	5,766	7,975	7,975	7,975

Notes: Robust standard errors, clustered at the district level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is households living in house, have male & unmarried household head and using regular heater for residential heating; the reference year is 2010. Columns 1 and 4 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2 and 5 add household–specific controls to the specification, including the type of residence. The preferred model results in Columns 3 and 6 further add heating sources in the residence to the specification.

Our preferred specification adds heating appliances to the model. The results in column 3 of Table 6 provide DiD estimates that are slightly lower than those in columns 1–2. Specifically, the treatment households increase their electricity expenditures by 20, 21, 19 and 27 percent respectively in 2012, 2014, 2016 and 2018, compared to their control counterparts. The additional control variables show that households with different heating appliances have varying electricity usage. For example, compared to the control group (living in apartments with central heating systems), households living in basic houses with private boilers and electric heaters have significantly higher electricity expenditures. On the other hand, households that use traditional stoves also have higher but statistically insignificant electricity expenditures. The preferred model in column 3 has an adjusted R^2 of 0.26, implying that our model explains the variations in electricity expenditures reasonably well.

The significance of the DiD estimates after controlling for the heating appliances used in residence is particularly informative about increased electricity expenditure. These results indicate that increased electricity expenditure is likely to be associated with the change in preference for energy rather than the availability of heating appliances. The convenience and health benefit makes it difficult to ignore electricity. Given the incentive (subsidy) to transition from the traditional energy sources during high demand periods, people make a permanent switch to electric appliances more generally, thus increasing their electricity expenditure significantly in the months without the subsidy. The policy therefore results in ancillary benefits of transition to cleaner energy.

The results from the analysis with electricity expenditures in non-winter months, during which treatment households do not receive any subsidy, is shown in columns 4–6 of Table 6. The coefficients of the DiD estimates are positive and significant, although slightly lower than those for the winter. Without any subsidy during the non-winter seasons, a positive DiD estimate indicates a positive effect on their electricity consumption. The finding may appear counter-intuitive in the first instance as, without any subsidy, treatment households are unlikely to change their electricity consumption differently than the control group. However, the change in their electricity consumption behaviour can be due to the change in treatment households' demand and preference for electricity. Since the treatment households do not pay for their nighttime electricity use in the winter season, they are likely to change their habit and continue to use electrical appliances for cooking and other purposes. This may allow them to switch from coal to electricity even in the non-winter months.

Also, being used to electricity may make the treatment households understand its value, making them unlikely to switch to non-electric fuels such as wood and coal in the non-winter months.

The findings in Table 6 show that treatment households increase their daytime electricity use significantly since they face free or lower-priced nighttime consumption. Such outcomes are comparable to the findings of other studies (Burke and Kurniawati, 2018; Boccard and Gautier, 2021; Xie et al., 2022). For example, Xie et al. (2022) find rural households in China experiencing sharp increases in heating expenditure after being enrolled in the clean heating program, even with the subsidized electricity prices. Households in Belgium increase their electricity consumption significantly when they face a lower price (Boccard and Gautier, 2021). A reduction in energy subsidy lowers the electricity demand in Indonesia (Burke and Kurniawati, 2018). However, our findings are in contrast to some previous studies like Bagnoli and Bertoméu-Sánchez (2022) who find subsidies to decrease expenditure on electricity. Showing that subsidy on electricity price in the winter season increases expenditure in winter and non-winter seasons, our findings provide additional insights into how consumers react when facing a subsidized energy price.

4.2. Common trend and placebo test

The validity of our estimates in Table 4 (Table 5) rely on the assumption that the difference in illness (respiratory illness) of the treatment and control households would have remained the same in the absence of the subsidy. To do so, we now investigate the same with the individuals for which the data has been collected in the non-winter months. This will serve as a placebo test since we would not expect any impact in the absence of the subsidy. In line with our expectation, we generally do not observe any significantly negative DiD estimates for the entire population or younger children, working-age population, and older people (Table 7).

We then repeat the analysis with the respiratory system illness using the non-winter sample. We again observe no significant negative effect except for small effects in 2012 (Table 8). Thus these two two placebo test results validate the common trend assumption for our models of illness and respiratory system illness.

Table 7: **Regression results of DiD models of the probability of illness: Placebo test**

	All age groups combined		Children (under 14 years)		Working age adults (15-60 years)		Older adults (over 60 years)	
Variable name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	0.004	0.007	0.011	0.018	0.006	0.009	-0.007	-0.009
	(0.008)	(0.015)	(0.012)	(0.025)	(0.008)	(0.015)	(0.051)	(0.101)
2012	0.016*	0.065***	0.052***	0.020	0.006	0.084***	-0.031	0.071
	(0.009)	(0.013)	(0.017)	(0.028)	(0.009)	(0.012)	(0.043)	(0.050)
2014	-0.006	0.038***	0.028*	-0.004	-0.008	0.066***	-0.094**	0.004
	(0.008)	(0.012)	(0.016)	(0.026)	(0.008)	(0.011)	(0.042)	(0.049)
2016	0.011	0.022**	0.048***	0.037**	-0.009	0.008	0.023	0.053
	(0.009)	(0.009)	(0.017)	(0.018)	(0.008)	(0.008)	(0.048)	(0.048)
2018	0.018**	0.039***	0.002	-0.015	0.027**	0.064***	0.005	0.056
	(0.009)	(0.010)	(0.013)	(0.017)	(0.011)	(0.012)	(0.046)	(0.048)
Treatment × 2012	-0.006	-0.012	-0.029	-0.031	-0.009	-0.008	0.111*	0.093
	(0.011)	(0.011)	(0.020)	(0.020)	(0.011)	(0.011)	(0.062)	(0.062)
Treatment × 2014	0.021**	0.016	-0.021	-0.023	0.019*	0.019*	0.146**	0.134**
	(0.010)	(0.010)	(0.019)	(0.019)	(0.011)	(0.011)	(0.060)	(0.060)
Treatment × 2016	0.004	-0.002	-0.026	-0.031	0.014	0.013	0.028	0.028
	(0.011)	(0.011)	(0.020)	(0.020)	(0.011)	(0.011)	(0.065)	(0.065)
Treatment × 2018	0.030**	0.030***	0.037**	0.031*	0.021	0.024*	0.070	0.081
	(0.012)	(0.012)	(0.017)	(0.017)	(0.014)	(0.014)	(0.063)	(0.064)
Individual's age (years)		0.002***						
		(0.000)						
Individual is female		0.012***		0.002		0.012***		0.028*
		(0.003)		(0.005)		(0.003)		(0.017)
Individual's education (years)		-0.002***		-0.007***		0.004***		-0.001
		(0.001)		(0.001)		(0.001)		(0.003)
Household size		0.008***		-0.013**		0.017***		0.026**
		(0.003)		(0.007)		(0.002)		(0.010)
Ln(consumption)		-0.182***		0.117		-0.321***		-0.360***
		(0.039)		(0.084)		(0.030)		(0.109)
Lives in ger		0.003		-0.001		0.009**		-0.003
		(0.004)		(0.007)		(0.005)		(0.028)
Private boiler		0.009		0.029		0.005		-0.020
		(0.015)		(0.026)		(0.015)		(0.100)
Electric heater		-0.021		-0.005		-0.025		-0.097
		(0.017)		(0.036)		(0.015)		(0.077)
Traditional stove		-0.003		-0.002		-0.004		-0.000
		(0.014)		(0.022)		(0.014)		(0.094)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.01	0.04	0.02	0.02	0.01	0.02	0.03	0.05
N	29,813	29,813	8,379	8,379	19,325	19,325	2,109	2,109

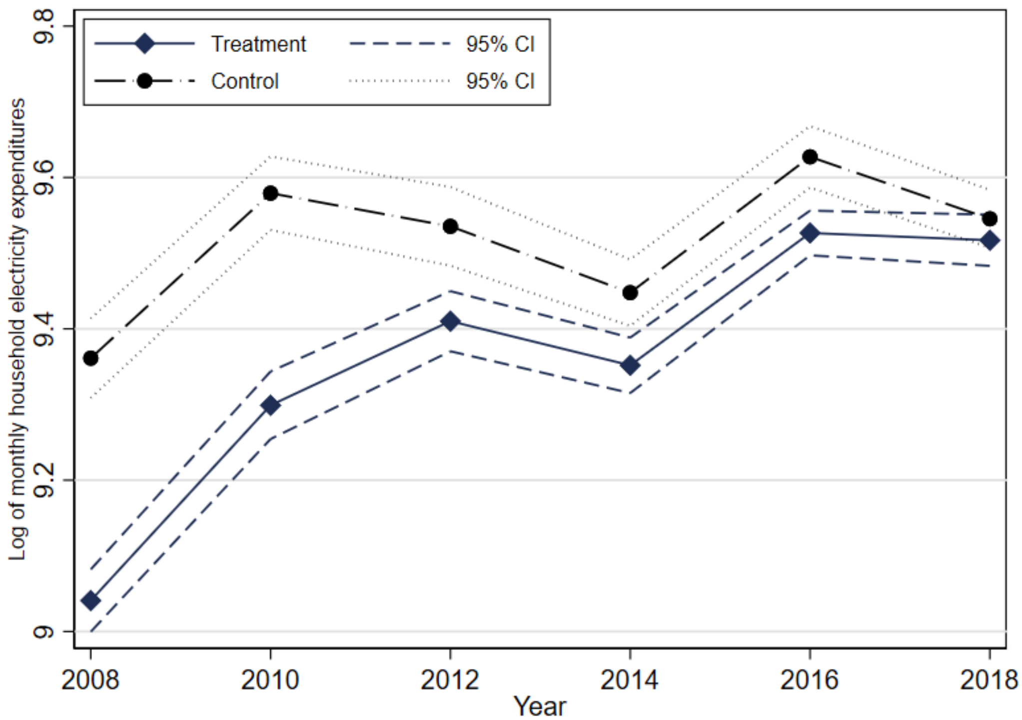
Notes: Standard errors, clustered at the household level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is individuals living in house, male and using regular heater for residential heating; the reference year is 2010. Columns 1,3,5 and 7 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2,4,6 and 8 add individual–specific controls to the specification, including the type of the residence and heating sources in residence.

Table 8: **Regression results of DiD models of the probability of having respiratory illness: Placebo test**

	All age groups combined		Children (under 14 years)		Working age adults (15-60 years)		Older adults (over 60 years)	
Variable name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	0.004	-0.005	0.008	0.008	0.001	-0.005*	0.002	-0.018
	(0.005)	(0.006)	(0.011)	(0.020)	(0.004)	(0.003)	(0.016)	(0.014)
2012	0.017***	0.043***	0.038**	0.005	0.008*	0.018***	0.024	0.036*
	(0.006)	(0.008)	(0.015)	(0.026)	(0.004)	(0.006)	(0.014)	(0.019)
2014	0.005	0.028***	0.019	-0.015	-0.003	0.007	0.016	0.027
	(0.005)	(0.007)	(0.015)	(0.024)	(0.004)	(0.005)	(0.015)	(0.019)
2016	0.013**	0.017***	0.036**	0.024	-0.003	-0.001	0.030	0.032
	(0.006)	(0.006)	(0.015)	(0.016)	(0.004)	(0.004)	(0.019)	(0.020)
2018	0.000	0.011**	-0.001	-0.019	-0.005	0.000	0.015	0.021
	(0.005)	(0.005)	(0.012)	(0.015)	(0.003)	(0.004)	(0.014)	(0.016)
Treatment × 2012	-0.015**	-0.017**	-0.025	-0.027	-0.012**	-0.012**	-0.007	-0.010
	(0.007)	(0.007)	(0.018)	(0.018)	(0.005)	(0.005)	(0.023)	(0.023)
Treatment × 2014	-0.002	-0.003	-0.015	-0.017	0.002	0.002	-0.003	-0.006
	(0.006)	(0.006)	(0.018)	(0.018)	(0.005)	(0.005)	(0.022)	(0.022)
Treatment × 2016	-0.006	-0.007	-0.022	-0.026	0.003	0.002	-0.008	-0.009
	(0.007)	(0.007)	(0.018)	(0.018)	(0.005)	(0.005)	(0.026)	(0.026)
Treatment × 2018	0.011*	0.012*	0.023	0.016	0.009*	0.009*	-0.008	-0.008
	(0.006)	(0.006)	(0.015)	(0.015)	(0.005)	(0.005)	(0.020)	(0.020)
Individual's age (years)		-0.000***						
		(0.000)						
Individual is female		0.001		0.001		0.002		0.008
		(0.002)		(0.005)		(0.001)		(0.007)
Individual's education (years)		-0.001		-0.008***		0.001***		0.000
		(0.000)		(0.001)		(0.000)		(0.001)
Household size		0.005***		-0.013**		0.001		0.001
		(0.002)		(0.006)		(0.001)		(0.004)
Ln(consumption)		-0.101***		0.120		-0.044***		-0.044
		(0.021)		(0.076)		(0.014)		(0.044)
Lives in ger		-0.002		-0.003		0.002		-0.002
		(0.003)		(0.006)		(0.002)		(0.010)
Private boiler		0.016**		0.031		0.009***		0.028
		(0.006)		(0.021)		(0.003)		(0.017)
Electric heater		0.001		0.003		0.001		-0.034**
		(0.013)		(0.034)		(0.008)		(0.017)
Traditional stove		0.007		0.005		0.007***		0.023*
		(0.005)		(0.017)		(0.002)		(0.012)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.01	0.02	0.02	0.03	0.00	0.00	0.01	0.01
N	29,813	29,813	8,379	8,379	19,325	19,325	2,109	2,109

Notes: Standard errors, clustered at the household level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is individuals living in house, male and using regular heater for residential heating; the reference year is 2010. Columns 1,3,5 and 7 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2,4,6 and 8 add individual–specific controls to the specification, including the type of the residence and heating sources in residence.

Similarly, for household electricity expenditure model, DiD estimates' validity relies on the assumption that the difference in the electricity expenditure between the treatment and control households would have remained the same in the absence of the subsidy. We validate this assumption in two ways. First, we examine the common trend graphically by plotting the (natural logarithm of) electricity expenditures (Figure 3).



Source: HSES, 2008-2018

Figure 3: Household monthly electricity expenditures in winter months, 2008-2018

The figure shows that the control households had higher electricity expenditures in 2008 and 2010 before the onset of the subsidy. The electricity expenditures grew at a similar rate from 2008 to 2010. However, in 2012 the treatment households increased their electricity expenditures while the control group slightly reduced their spending. Although both groups reduced their electricity expenditures in 2014 from the previous year, the difference in their electricity expenditures decreased. The electricity expenditures for both groups increased in 2016 and declined in 2018, but the difference was even smaller in 2018. The common trend graph confirms that the DiD estimates are valid for evaluating the effectiveness of the subsidy.

Second, we check the policy's effectiveness by performing a placebo test with a false treatment. In that test, we estimate Equation (1) using the same control group, but households living in *apartments* (rather than gers) located in zones 1, 2, and 3 (the polluting zones) are considered as treatment households. These treatment households do not rely on coal as they have a central heating system and should not be affected by the policy intervention.[13] Note that we exclude 2012 survey round data from this placebo test as they do not have subdistrict level location information for the households to precisely define the zones.

We present the placebo test results in Table 9, again separately for households surveyed in winter and non-winter seasons. The results in column 1 for the winter sample indicate that, compared to the control group, the alternative treatment households had around 12 percent higher electricity expenditures in 2010. The survey year-fixed effects indicate that the control group reduces their electricity expenditures over time, although the coefficients are not always statistically significant. The DiD estimates show the difference in changes in electricity expenditures between the two groups but are not statistically significant at any conventional level of significance. Adding household-specific control variables in column 2 does not affect the results. The DiD estimates in columns 3–4 for the non-winter months are also statistically insignificant. Overall, the results validate the DiD estimates in Table 6.

4.3. Robustness checks

We undertake several robustness checks to ensure that our choice of data, estimation technique and model and data do not drive the results. First, dropping observations for which we have corrected for missing illness values (assuming no illness) do not affect our conclusions (Tables A.1–A.2). Second, as the preferred technique, we used the linear probability model (LPM) to estimate illness models. Now we estimate those models with probit and logit techniques to see whether the results are sensitive to different estimation techniques (Tables A.3–A.6). In both cases, we arrive at a similar conclusion.

[13] Note that, as a consequence of selecting households living in apartments, for both for the treatment and the control groups, control variables like property type and heating appliances are dropped from the model.

Table 9: **Regression results of DiD models of the effect of electricity subsidy on household monthly electricity expenditures: Placebo test**

	Winter months		Non-winter months	
Variable	(1)	(2)	(3)	(4)
Treatment	0.112	0.061	-0.167	-0.218*
	(0.083)	(0.045)	(0.089)	(0.085)
2014	-0.197***	-0.203***	-0.159***	-0.181***
	(0.032)	(0.022)	(0.017)	(0.018)
2016	-0.021	-0.023	-0.029	-0.028
	(0.047)	(0.030)	(0.062)	(0.058)
2018	-0.074	-0.093**	-0.106*	-0.123***
	(0.058)	(0.031)	(0.046)	(0.028)
Treatment × 2014	-0.029	-0.023	0.065	0.066
	(0.142)	(0.111)	(0.077)	(0.069)
Treatment × 2016	0.074	0.088	0.030	0.006
	(0.087)	(0.055)	(0.135)	(0.130)
Treatment × 2018	-0.078	-0.092	0.105	0.064
	(0.079)	(0.050)	(0.073)	(0.065)
Household head's age (years)		0.005***		0.004***
		(0.001)		(0.000)
Household head is female		-0.047		0.007
		(0.029)		(0.015)
Household head's education (years)		0.009**		0.010**
		(0.003)		(0.004)
Household head is married		0.026		0.069**
		(0.027)		(0.027)
Share of working members		0.022		0.034
		(0.034)		(0.059)
Household size		0.089***		0.081***
		(0.007)		(0.006)
Ln(income)		0.043***		0.032**
		(0.005)		(0.010)
Subdistrict fixed effects	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes
Adjusted R^2	0.06	0.23	0.06	0.20
Number of households	2,184	2,184	2,851	2,851

Notes: Robust standard errors, clustered at the district level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is households with male & unmarried household head and the reference year is 2010. Columns 1 and 3 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2 and 4 add household–specific controls to the specification. Residence type and heating source in the residence are not included in the model as all households live in apartments connected to central heating.

Next, we examine whether covariate selection significantly modifies our results. In our result tables for the illness models, we present two sets of results – one without covariates and the other with them. The similar results in both cases indicate that our results do not depend heavily on the included covariates. Furthermore, using education as categories (instead of continuous) (Tables A.7–A.8) and/or age in quadratic form (Table A.9) does not affect our results. Thus, all the robustness check results support our finding that individuals benefit from the support program as their likelihood of reporting illness and respiratory illness reduces with the introduction of the subsidy.[14]

We also investigate the sensitivity of the estimated impact of the subsidy with different models and data. First, when we use the level value of electricity expenditure, we arrive at a similar conclusion (Table A.10). Second, our results do not change qualitatively when we use per capita electricity expenditures and per capita income in the model (Table A.11). A similar result is also observed when using equivalized income with either the OECD scale (Table A.12) or the square root of the family size scale (Table A.13). Using education as a categorical (rather than a continuous) variable and/or age in quadratic form in the model provide similar results (Tables A.14–A.15).

We also examine the consequence of using a pooled dataset or a subsample. In that, rather than conducting analysis separately for winter and non-winter samples, we analyze electricity expenditures with the entire sample of 13,741 households. Again, we observe results that are similar to our main findings (Table A.16). Repeating the analysis with only 2010 and 2012 data, since it can be argued that the introduction of subsidy is really a shock in 2012 but not afterwards, provides a similar coefficient for the later period (Table A.17). Again, all of our robustness checks validate our finding that the subsidy on nighttime electricity consumption increases the electricity expenditure of the affected households.

4.4. Policy implications

We find that a subsidy on nighttime electricity consumption reduces the recipient households' reported sicknesses. While we have not directly investigated whether the program achieves its intended consequence of reducing pollution, a reduced sickness for the treated households indicates its likely success. The estimated health benefit occurs even when (by design) the benefit spills over to the control households in the form of reducing pollution.

Therefore, our findings are important for Mongolia and other countries that provide substantial energy subsidies. Country-level studies find energy subsidy to improve household health and welfare, including Argentina (Giuliano et al., 2020), China (Teng et al., 2019; Liu et al., 2020), Indonesia (Burke and Kurniawati, 2018), Pakistan (Khalid and Salman, 2020), Turkey (Cesur et al.,

[14] All the mentioned results are available from the corresponding author upon request.

2017) and the United States (Hahn and Metcalfe, 2021). These short-term health gains will have substantial long-term socio-economic benefits as healthier children will have better education outcomes and be more productive members of society. On the other hand, improved health outcomes will reduce morbidity costs of air pollution, such as health care expenditures and utilization (Liu and Ao, 2021).

We also find an unintended positive consequence of the subsidy. The preference of the beneficiary households changes in a way that increases their daytime electricity expenditure in winter months, when they do not receive any subsidy on their electricity consumption. They even increase their electricity expenditure in the non-winter season, when there is no provision of subsidy on daytime or nightime expenditure on electricity.

Our finding aligns with previous studies that describe habit formation as a crucial channel to stimulate future use of products and services. For example, Meriggi et al. (2021) study how a short-term subsidy for a new product affects its future demand and find that short-term subsidies increase future willingness-to-pay. Dupas (2014) find short-run subsidies for new health products to impact its' long-run adoption by raising knowledge about the usefulness of the product. Along that line, Hussam et al. (2022) find that monitoring and incentives persistently raise handwashing in rural India, providing evidence for rational habit formation.[15]

In case of energy, Boccard and Gautier (2021) find that subsidies to encourage renewable energy use result in a higher than expected increase in electricity consumption, which is counter to the original policy's intended outcome. High-frequency information has been found to affect residential electricity usage beyond the short and medium run, providing evidence of habit formation (Jessoe and Rapson, 2014). Thus, our findings indicate an important channel that can induce increased electricity use (and decreased dirty energy use), further raising the health benefit.

Due to the lack of electricity usage data in the household survey, our analysis focuses on electricity expenditures instead of actual consumption. To get a more precise idea about the program, we would ideally like to know the change in electricity usage, a more policy-relevant variable.

[15]Persistence in behavior can result from changes in the production function, knowledge acquisition (explicit or tacit) of the costs and benefit of actions, influence of social interactions, or the changes in consumption stock (Hussam et al., 2021, 2022). We have not distinguished among those channels as existing literature typically defines long-run persistence of temporary interventions as habit formation.

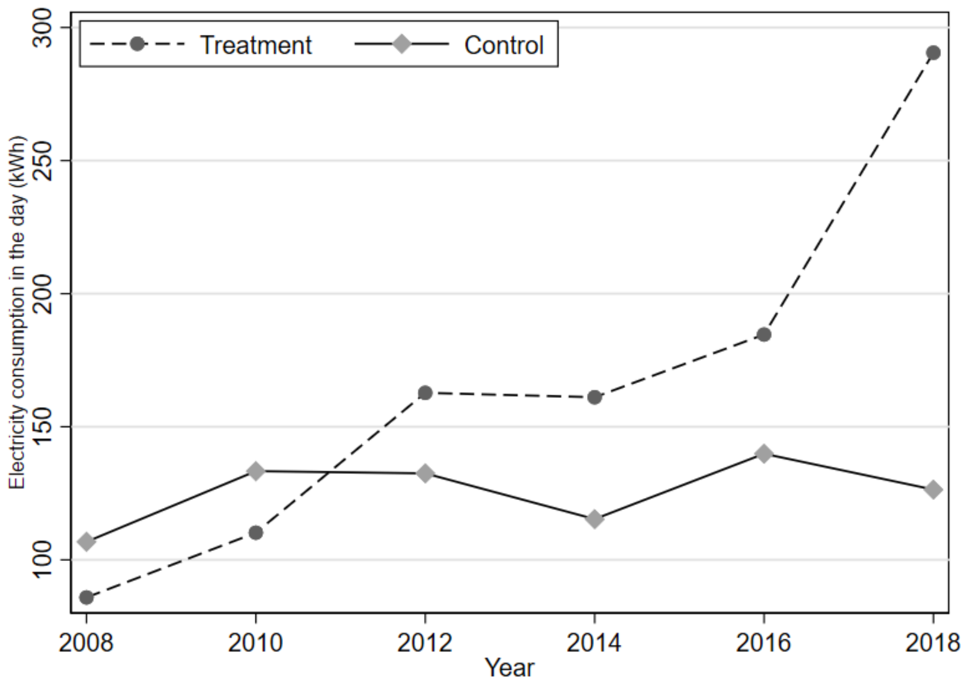
Therefore, using the available data, we have made a back-of-the-envelope calculation of overtime electricity consumption for treatment and control households.[16]

Based on the calculations, Figure 4 shows the electricity usage before the onset of the intervention in 2010 and the subsequent years. The treatment households consume around 86 kWh and 110 kWh of electricity a day in 2008 and 2010, respectively, against the control group's usage of 107 kWh and 133 kWh at the same time. After the subsidy commence in 2012, the treatment households increase their electricity consumption to 162 kWh, while the control households use 132 kWh. The treatment households' electricity usage are 162 kWh in 2014, 185 kWh in 2016, and 290 kWh in 2018. The control households have a relatively stable electricity usage in the same period, fluctuating between 107 kWh and 140 kWh. The pattern reassures us that the treatment households adjust their electricity consumption behaviour as a result of the subsidy program.

It is also important to note that coal-based power plants generate electricity in Ulaanbaatar. Therefore, the subsidized electricity used for heating in winter can still pollute the environment and negatively affect the local population's health. However, the advantage of subsidizing electricity is that the government can monitor and manage the pollution generated at the thermal power plant level more easily than at the household level. Power plants are also likely to be more efficient in using energy than individual heating units. Another benefit is that power plants generate outdoor

[16] We obtained some data about the received subsidy from the Ministry of Energy through personal communication. We have the number of households (treatment households) who received the subsidy, the total electricity consumed in kWh during the subsidy months, and the total monetary amount of subsidy provided for 2017 and 2018. Relying on these aggregate figures, we calculated the average electricity consumption per household per month by dividing total electricity consumption (in kWh) by the number of households. The average electricity consumption per household gives us an approximate electricity usage at nighttime during the subsidy months from November until April. However, the average electricity consumption was below the cap of 700kWh of free electricity at night, indicating that households did not pay for nighttime use in November and December 2018. Note that the aggregate data did not have information about the household appliance capacity, such as 220V versus 380V.

Since we know that nighttime electricity is free from the above calculation, we estimated the electricity usage in the daytime for the treatment households using the tariffs. The daytime tariff (6 am–9 pm) is US$0.043 per kWh, while the nighttime tariff (9 pm–6 am) is US$0.032 per kWh. The monthly base tariff is US$0.828 per month. First, we subtracted the base tariff from household monthly electricity expenditures to estimate the daytime consumption expenditures. Then we divided the daytime expenditures by daytime tariff to calculate daytime electricity consumption. We added daytime usage to the nighttime usage calculated from the aggregate figures above to get the total electricity consumption per household. Since there was an increase of 15-20 percent in the average nighttime electricity consumption per household from 2017 to 2018, we reduced the nighttime electricity consumption by 10 percent from the 2017 usage to calculate 2016 usage. The same procedure is applied to get the electricity consumption for all previous years. However, we used the discount for nighttime usage for a 50 percent discount subsidy in 2012-2016. Instead of the flat usage rate for the control households, we averaged nighttime and daytime rates to estimate the price per kWh. Then we subtracted the base rate from the electricity expenditures and divided the difference by average price to arrive at total electricity consumption.

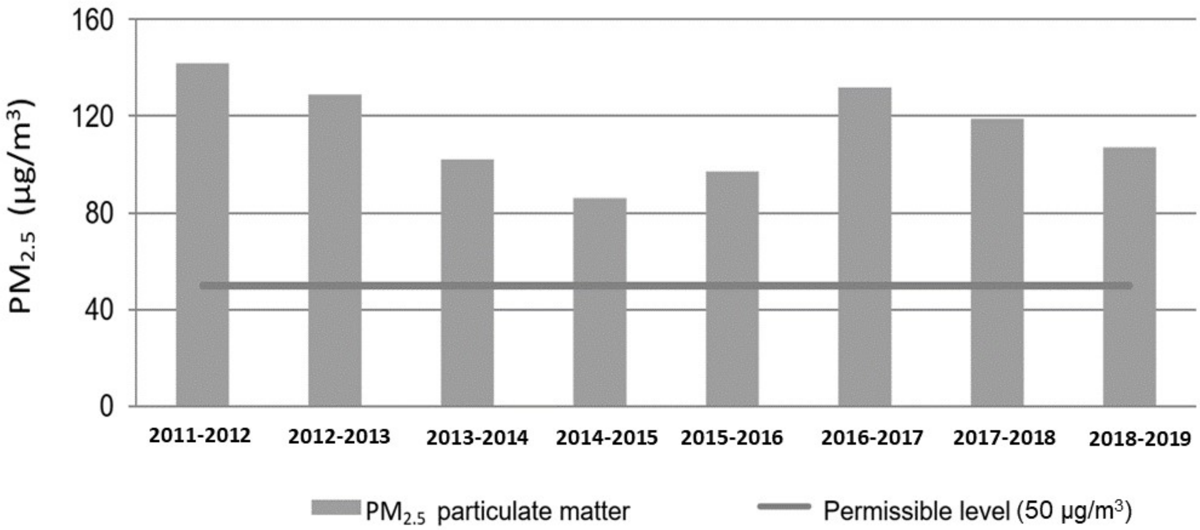


Source: HSES, 2008-2018

Figure 4: Back of the envelope analysis of household electricity consumption (kWh), 2008-2018

pollution, which is likely to be less severe than the indoor pollution generated by individual coal-based heating and cooking units.

It is important to note that the huge electricity subsidy imposes a huge fiscal burden, and the benefit needs to be weighed against the opportunity cost of the subsidy on welfare (Coady et al., 2017). For example, in Mongolia, it is uncertain how long the subsidy will be available and whether it is fiscally feasible for a prolonged period (World Bank, 2019). In this context, we argue that, while comparing to costs of a subsidy, benefit from the intended as well as unintended consequences should be considered. This is particularly because the overtime pollution level remains very high in Mongolia. The distribution of $PM_{2.5}$ levels in Ulaanbaatar during cold winter months from October to April in 2011-2019 in Figure 5 demonstrates so as an example. The situation is similar in many other countries around the world (Currie et al., 2014; Graff Zivin and Neidell, 2013; Arceo et al., 2016).



Source: NAMEM (2019)

Figure 5: $PM_{2.5}$ level during winter months (October-April) in Ulaanbaatar, 2011-2019

5. Conclusion

We investigate the impact of an electricity subsidy program on the likelihood of reporting illness and household electricity expenditures in Ulaanbaatar, Mongolia. For our investigation, we use five rounds of household survey data covering 2010-2018 and difference-in-differences models employing individuals and households eligible for the subsidy as treatment vs those ineligible as the control group. The results suggest a positive effect of the policy that reduces the likelihood of individuals' reporting illnesses, especially for children and working-age people. Our analysis also indicates that households receiving the subsidy increase their electricity expenditures significantly than the control households during the cold winter months and non-winter months. These findings are robust to alternative specifications.

Our investigation adds to the existing literature on the effectiveness of government intervention to increase access to electricity and reduce air pollution. The study shows that electricity subsidy effectively reduces the prevalence of respiratory illnesses among the general population and can even induce households to permanently increase their non-subsidised electricity usage. The short-term gains from reduced air pollution and improved health benefits further improve productivity and raise living standards in the long run. On the other hand, electricity subsidy changes the habit of the recipient households who increase their expenditure on (and thereby consumption of) electricity when the subsidy is not provided. This will allow the subsidy to indirectly contribute in improving health of the affected population. Therefore, in determining the usefulness of the electricity subsidy program, its fiscal cost needs to be compared with the benefit it generates, including the unintended benefit of increased electricity usage in winter and non-winter seasons.

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Appendix tables

Table A.1: **Regression results of DiD models of the probability of illness: dropped missing illness values**

	All age groups combined		Children (under 14 years)		Working age adults (15-60 years)		Older adults (over 60 years)	
Variable name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	0.029**	0.015	0.050*	-0.018	0.029**	0.032	0.014	0.061
	(0.012)	(0.022)	(0.026)	(0.033)	(0.012)	(0.023)	(0.052)	(0.109)
2012	0.047***	0.073***	0.069**	0.004	0.046***	0.108***	0.004	0.116**
	(0.013)	(0.018)	(0.028)	(0.045)	(0.013)	(0.016)	(0.049)	(0.057)
2014	0.044***	0.062***	0.101***	0.030	0.035***	0.091***	-0.046	0.053
	(0.013)	(0.017)	(0.030)	(0.046)	(0.013)	(0.015)	(0.051)	(0.057)
2016	0.011	0.015	0.054**	0.027	-0.004	0.012	0.010	0.037
	(0.012)	(0.012)	(0.026)	(0.027)	(0.010)	(0.011)	(0.056)	(0.056)
2018	0.071***	0.080***	0.105***	0.065**	0.053***	0.084***	0.067	0.128**
	(0.013)	(0.015)	(0.027)	(0.032)	(0.013)	(0.014)	(0.052)	(0.054)
Treatment × 2012	-0.064***	-0.075***	-0.104***	-0.115***	-0.058***	-0.062***	0.007	-0.011
	(0.016)	(0.016)	(0.035)	(0.035)	(0.016)	(0.016)	(0.066)	(0.066)
Treatment × 2014	-0.058***	-0.066***	-0.117***	-0.117***	-0.051***	-0.056***	0.031	0.021
	(0.016)	(0.016)	(0.037)	(0.037)	(0.016)	(0.017)	(0.068)	(0.069)
Treatment × 2016	0.009	0.002	-0.003	-0.010	0.007	0.002	0.004	0.014
	(0.015)	(0.015)	(0.034)	(0.034)	(0.015)	(0.014)	(0.072)	(0.072)
Treatment × 2018	-0.048***	-0.055***	-0.110***	-0.110***	-0.026	-0.030*	-0.010	-0.017
	(0.017)	(0.017)	(0.034)	(0.034)	(0.017)	(0.017)	(0.070)	(0.070)
Individual's age (years)		0.002***						
		(0.000)						
Individual is female		0.018***		-0.002		0.024***		0.025
		(0.004)		(0.008)		(0.004)		(0.019)
Individual's education (years)		-0.008***		-0.015***		0.000		-0.001
		(0.001)		(0.002)		(0.001)		(0.004)
Household size		0.002		-0.024**		0.012***		0.030***
		(0.004)		(0.011)		(0.003)		(0.012)
Ln(consumption)		-0.070		0.251*		-0.228***		-0.378***
		(0.050)		(0.139)		(0.038)		(0.126)
Lives in ger		0.004		0.028**		-0.001		-0.037
		(0.006)		(0.013)		(0.006)		(0.028)
Private boiler		0.030		0.095***		0.015		-0.077
		(0.023)		(0.032)		(0.024)		(0.115)
Electric heater		-0.016		-0.098***		0.004		0.207*
		(0.023)		(0.031)		(0.030)		(0.124)
Traditional stove		0.010		0.064***		-0.004		-0.041
		(0.020)		(0.024)		(0.020)		(0.104)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.01	0.03	0.02	0.03	0.01	0.02	0.04	0.05
N	21,579	21,579	6,114	6,114	13,882	13,882	1,583	1,583

Notes: Standard errors, clustered at the household level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is individuals living in house, male and using regular heater for residential heating; the reference year is 2010. Columns 1,3,5 and 7 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2,4,6 and 8 add individual–specific controls to the specification, including the type of the residence and heating sources in residence.

Table A.2: **Regression results of DiD models of the probability of having respiratory illness: dropped missing illness values**

	All age groups combined		Children (under 14 years)		Working age adults (15-60 years)		Older adults (over 60 years)	
Variable name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	0.020**	-0.011	0.042*	-0.014	0.014**	-0.003	-0.020	-0.036
	(0.008)	(0.009)	(0.025)	(0.032)	(0.007)	(0.006)	(0.029)	(0.027)
2012	0.025***	0.051***	0.050*	-0.011	0.019***	0.012	-0.010	0.022
	(0.009)	(0.012)	(0.026)	(0.042)	(0.007)	(0.009)	(0.028)	(0.030)
2014	0.041***	0.061***	0.102***	0.034	0.022***	0.015*	-0.008	0.023
	(0.010)	(0.012)	(0.029)	(0.043)	(0.008)	(0.009)	(0.030)	(0.031)
2016	0.016**	0.018**	0.048**	0.023	0.002	-0.000	-0.011	-0.005
	(0.008)	(0.008)	(0.025)	(0.026)	(0.005)	(0.005)	(0.030)	(0.029)
2018	0.043***	0.053***	0.091***	0.053*	0.024***	0.021**	-0.016	0.001
	(0.009)	(0.010)	(0.025)	(0.030)	(0.008)	(0.008)	(0.027)	(0.026)
Treatment × 2012	-0.031***	-0.035***	-0.076**	-0.087***	-0.019**	-0.020**	0.023	0.025
	(0.011)	(0.011)	(0.032)	(0.032)	(0.009)	(0.009)	(0.035)	(0.035)
Treatment × 2014	-0.046***	-0.047***	-0.106***	-0.105***	-0.028***	-0.029***	-0.009	-0.009
	(0.012)	(0.012)	(0.035)	(0.035)	(0.010)	(0.010)	(0.035)	(0.035)
Treatment × 2016	0.010	0.010	0.011	0.007	0.005	0.004	0.037	0.040
	(0.012)	(0.011)	(0.032)	(0.032)	(0.008)	(0.008)	(0.038)	(0.038)
Treatment × 2018	-0.039***	-0.041***	-0.093***	-0.092***	-0.024**	-0.025**	0.018	0.019
	(0.012)	(0.012)	(0.032)	(0.032)	(0.010)	(0.010)	(0.034)	(0.034)
Individual's age (years)		-0.001***						
		(0.000)						
Individual is female		0.005*		0.001		0.008***		0.008
		(0.003)		(0.008)		(0.002)		(0.009)
Individual's education (years)		-0.004***		-0.015***		-0.001		0.003
		(0.001)		(0.002)		(0.001)		(0.002)
Household size		0.004*		-0.022**		-0.003		0.008
		(0.003)		(0.011)		(0.002)		(0.005)
Ln(consumption)		-0.089***		0.237*		0.028		-0.124**
		(0.033)		(0.131)		(0.022)		(0.061)
Lives in ger		0.003		0.024**		0.001		-0.010
		(0.005)		(0.012)		(0.004)		(0.013)
Private boiler		0.031***		0.066**		0.026***		-0.016
		(0.011)		(0.031)		(0.009)		(0.013)
Electric heater		-0.021		-0.080***		-0.001		0.070
		(0.017)		(0.027)		(0.022)		(0.064)
Traditional stove		0.022***		0.054**		0.017***		0.024**
		(0.006)		(0.024)		(0.003)		(0.012)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.01	0.04	0.02	0.03	0.01	0.01	0.01	0.01
N	21,579	21,579	6,114	6,114	13,882	13,882	1,583	1,583

Notes: Standard errors, clustered at the household level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is individuals living in house, male and using regular heater for residential heating; the reference year is 2010. Columns 1,3,5 and 7 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2,4,6 and 8 add individual–specific controls to the specification, including the type of the residence and heating sources in residence.

Table A.3: **Regression results of DiD models of the probability of illness: probit model**

	All age groups combined		Children (under 14 years)		Working age adults (15-60 years)		Older adults (over 60 years)	
Variable name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	0.034**	0.018	0.062*	-0.074	0.034**	0.036	0.017	0.054
	(0.014)	(0.028)	(0.033)	(0.081)	(0.013)	(0.025)	(0.053)	(0.121)
2012	0.047***	0.079***	0.076**	0.016	0.044***	0.098***	0.010	0.129**
	(0.013)	(0.017)	(0.033)	(0.047)	(0.013)	(0.016)	(0.051)	(0.059)
2014	0.047***	0.075***	0.108***	0.041	0.038***	0.088***	-0.050	0.060
	(0.014)	(0.017)	(0.032)	(0.046)	(0.014)	(0.016)	(0.059)	(0.064)
2016	0.016	0.026*	0.066**	0.040	-0.002	0.012	0.015	0.044
	(0.014)	(0.014)	(0.032)	(0.032)	(0.014)	(0.014)	(0.057)	(0.056)
2018	0.070***	0.085***	0.111***	0.072**	0.053***	0.079***	0.069	0.134***
	(0.013)	(0.014)	(0.030)	(0.034)	(0.013)	(0.013)	(0.049)	(0.051)
Treatment × 2012	-0.066***	-0.075***	-0.115***	-0.126***	-0.057***	-0.057***	-0.001	-0.017
	(0.017)	(0.016)	(0.040)	(0.039)	(0.016)	(0.016)	(0.068)	(0.068)
Treatment × 2014	-0.062***	-0.072***	-0.124***	-0.123***	-0.054***	-0.057***	0.035	0.019
	(0.017)	(0.017)	(0.040)	(0.039)	(0.017)	(0.017)	(0.075)	(0.075)
Treatment × 2016	0.002	-0.008	-0.021	-0.028	0.005	0.000	-0.002	0.003
	(0.017)	(0.016)	(0.038)	(0.037)	(0.017)	(0.017)	(0.073)	(0.072)
Treatment × 2018	-0.049***	-0.056***	-0.114***	-0.114***	-0.030*	-0.032**	-0.014	-0.020
	(0.016)	(0.016)	(0.037)	(0.037)	(0.016)	(0.016)	(0.067)	(0.066)
Individual's age (years)		0.001***						
		(0.000)						
Individual is female		0.017***		-0.001		0.021***		0.030
		(0.004)		(0.008)		(0.004)		(0.019)
Individual's education (years)		-0.005***		-0.016***		0.003***		0.001
		(0.001)		(0.003)		(0.001)		(0.004)
Household size		0.004		-0.022**		0.012***		0.033***
		(0.003)		(0.011)		(0.003)		(0.012)
Ln(consumption)		-0.104**		0.226*		-0.213***		-0.406***
		(0.042)		(0.135)		(0.036)		(0.128)
Lives in ger		0.004		0.027**		0.001		-0.035
		(0.006)		(0.012)		(0.006)		(0.029)
Private boiler		0.034		0.158**		0.015		-0.070
		(0.028)		(0.078)		(0.024)		(0.125)
Electric heater		-0.015		-0.130**		-0.000		0.153
		(0.022)		(0.055)		(0.023)		(0.097)
Traditional stove		0.018		0.133*		-0.000		-0.028
		(0.026)		(0.076)		(0.022)		(0.114)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo-R^2	0.02	0.05	0.03	0.04	0.02	0.03	0.04	0.05
N	21,985	21,985	6,160	6,160	14,233	14,233	1,592	1,592

Notes: Standard errors, clustered at the household level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is individuals living in house, male and using regular heater for residential heating; the reference year is 2010. Columns 1,3,5 and 7 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2,4,6 and 8 add individual–specific controls to the specification, including the type of the residence and heating sources in residence.

Table A.4: **Regression results of DiD models of the probability of having respiratory illness: probit model**

	All age groups combined		Children (under 14 years)		Working age adults (15-60 years)		Older adults (over 60 years)	
Variable name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	0.026**	-0.039	0.053*	-0.053	0.019**	-0.121***	-0.017	-0.191***
	(0.011)	(0.026)	(0.032)	(0.073)	(0.009)	(0.012)	(0.023)	(0.034)
2012	0.029***	0.050***	0.058*	0.005	0.021***	0.013	-0.007	0.015
	(0.011)	(0.012)	(0.032)	(0.044)	(0.008)	(0.009)	(0.021)	(0.017)
2014	0.044***	0.060***	0.107***	0.046	0.024***	0.016*	-0.005	0.017
	(0.010)	(0.011)	(0.031)	(0.043)	(0.008)	(0.009)	(0.022)	(0.017)
2016	0.023**	0.022**	0.061**	0.037	0.005	0.003	-0.008	-0.001
	(0.010)	(0.009)	(0.031)	(0.031)	(0.009)	(0.008)	(0.022)	(0.015)
2018	0.046***	0.050***	0.098***	0.062*	0.026***	0.020**	-0.011	0.003
	(0.010)	(0.009)	(0.030)	(0.033)	(0.008)	(0.008)	(0.020)	(0.014)
Treatment × 2012	-0.036***	-0.032***	-0.088**	-0.098***	-0.022**	-0.021**	0.018	0.016
	(0.013)	(0.011)	(0.039)	(0.038)	(0.010)	(0.009)	(0.029)	(0.020)
Treatment × 2014	-0.049***	-0.043***	-0.110***	-0.107***	-0.030***	-0.028***	-0.025	-0.020
	(0.013)	(0.011)	(0.038)	(0.037)	(0.011)	(0.010)	(0.033)	(0.022)
Treatment × 2016	-0.001	-0.000	-0.009	-0.014	0.000	-0.001	0.029	0.023
	(0.013)	(0.011)	(0.037)	(0.036)	(0.011)	(0.010)	(0.030)	(0.021)
Treatment × 2018	-0.041***	-0.036***	-0.099***	-0.096***	-0.025**	-0.024**	0.012	0.010
	(0.013)	(0.011)	(0.036)	(0.035)	(0.010)	(0.010)	(0.029)	(0.020)
Individual's age (years)		-0.001***						
		(0.000)						
Individual is female		0.005*		0.002		0.007***		0.007
		(0.002)		(0.007)		(0.002)		(0.006)
Individual's education (years)		-0.002***		-0.018***		0.000		0.002*
		(0.001)		(0.003)		(0.000)		(0.001)
Household size		0.005**		-0.018*		-0.002		0.005
		(0.002)		(0.010)		(0.001)		(0.004)
Ln(consumption)		-0.101***		0.196		0.025		-0.081**
		(0.031)		(0.126)		(0.019)		(0.037)
Lives in ger		0.003		0.023**		0.001		-0.008
		(0.004)		(0.012)		(0.003)		(0.009)
Private boiler		0.063**		0.112		0.145***		-0.013
		(0.026)		(0.070)		(0.012)		(0.012)
Electric heater		-0.019		-0.121**		-0.002		0.213***
		(0.019)		(0.054)		(0.014)		(0.041)
Traditional stove		0.059**		0.104		0.139***		0.184***
		(0.025)		(0.067)		(0.011)		(0.031)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo-R^2	0.02	0.10	0.03	0.05	0.03	0.03	0.02	0.05
N	21,985	21,985	6,160	6,160	14,233	14,233	1,592	1,592

Notes: Standard errors, clustered at the household level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is individuals living in house, male and using regular heater for residential heating; the reference year is 2010. Columns 1,3,5 and 7 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2,4,6 and 8 add individual–specific controls to the specification, including the type of the residence and heating sources in residence.

Table A.5: **Regression results of DiD models of the probability of illness: logit model**

	All age groups combined		Children (under 14 years)		Working age adults (15-60 years)		Older adults (over 60 years)	
Variable name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	0.035**	0.015	0.061*	-0.084	0.034**	0.037	0.018	0.058
	(0.014)	(0.030)	(0.034)	(0.098)	(0.014)	(0.025)	(0.053)	(0.118)
2012	0.047***	0.074***	0.075**	0.012	0.044***	0.094***	0.009	0.125**
	(0.014)	(0.016)	(0.034)	(0.046)	(0.013)	(0.015)	(0.051)	(0.058)
2014	0.048***	0.073***	0.106***	0.038	0.039***	0.085***	-0.050	0.055
	(0.014)	(0.016)	(0.033)	(0.045)	(0.014)	(0.015)	(0.061)	(0.065)
2016	0.017	0.026*	0.066**	0.039	-0.002	0.012	0.014	0.042
	(0.014)	(0.014)	(0.033)	(0.033)	(0.015)	(0.015)	(0.057)	(0.055)
2018	0.068***	0.081***	0.107***	0.067*	0.052***	0.075***	0.066	0.129***
	(0.013)	(0.013)	(0.032)	(0.034)	(0.013)	(0.013)	(0.048)	(0.050)
Treatment × 2012	-0.065***	-0.069***	-0.112***	-0.118***	-0.056***	-0.055***	0.002	-0.011
	(0.017)	(0.016)	(0.041)	(0.039)	(0.016)	(0.016)	(0.067)	(0.067)
Treatment × 2014	-0.063***	-0.068***	-0.122***	-0.117***	-0.056***	-0.056***	0.033	0.025
	(0.017)	(0.016)	(0.040)	(0.039)	(0.017)	(0.017)	(0.077)	(0.077)
Treatment × 2016	0.001	-0.008	-0.021	-0.026	0.004	0.001	0.000	0.011
	(0.017)	(0.016)	(0.039)	(0.037)	(0.018)	(0.017)	(0.073)	(0.072)
Treatment × 2018	-0.047***	-0.052***	-0.111***	-0.106***	-0.030*	-0.031**	-0.013	-0.015
	(0.016)	(0.015)	(0.038)	(0.037)	(0.016)	(0.016)	(0.066)	(0.065)
Individual's age (years)		0.001***						
		(0.000)						
Individual is female		0.015***		-0.001		0.021***		0.027
		(0.004)		(0.008)		(0.004)		(0.019)
Individual's education (years)		-0.005***		-0.017***		0.003***		0.001
		(0.001)		(0.003)		(0.001)		(0.003)
Household size		0.004		-0.022**		0.011***		0.033***
		(0.003)		(0.010)		(0.003)		(0.012)
Ln(consumption)		-0.104***		0.223*		-0.202***		-0.407***
		(0.039)		(0.128)		(0.035)		(0.128)
Lives in ger		0.004		0.026**		0.001		-0.034
		(0.006)		(0.012)		(0.006)		(0.029)
Private boiler		0.034		0.165*		0.012		-0.075
		(0.029)		(0.095)		(0.023)		(0.122)
Electric heater		-0.014		-0.136**		0.002		0.147*
		(0.021)		(0.061)		(0.021)		(0.088)
Traditional stove		0.019		0.139		-0.001		-0.035
		(0.027)		(0.093)		(0.022)		(0.111)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo-R^2	0.02	0.05	0.03	0.05	0.02	0.03	0.04	0.05
N	21,985	21,985	6,160	6,160	14,233	14,233	1,592	1,592

Notes: Standard errors, clustered at the household level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is individuals living in house, male and using regular heater for residential heating; the reference year is 2010. Columns 1,3,5 and 7 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2,4,6 and 8 add individual–specific controls to the specification, including the type of the residence and heating sources in residence.

Table A.6: **Regression results of DiD models of the probability of having respiratory illness: logit model**

	All age groups combined		Children (under 14 years)		Working age adults (15-60 years)		Older adults (over 60 years)	
Variable name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	0.027**	-0.038	0.053	-0.059	0.019**	-0.204***	-0.016	-0.224***
	(0.012)	(0.030)	(0.034)	(0.085)	(0.009)	(0.034)	(0.023)	(0.014)
2012	0.029***	0.044***	0.058*	0.000	0.021**	0.012	-0.006	0.011
	(0.011)	(0.011)	(0.034)	(0.043)	(0.008)	(0.009)	(0.020)	(0.012)
2014	0.044***	0.054***	0.104***	0.040	0.024***	0.015*	-0.005	0.012
	(0.011)	(0.010)	(0.032)	(0.042)	(0.009)	(0.009)	(0.021)	(0.012)
2016	0.024**	0.020**	0.061*	0.035	0.006	0.003	-0.008	-0.001
	(0.011)	(0.008)	(0.033)	(0.031)	(0.010)	(0.008)	(0.022)	(0.012)
2018	0.045***	0.044***	0.095***	0.056*	0.025***	0.018**	-0.012	0.001
	(0.010)	(0.008)	(0.031)	(0.033)	(0.008)	(0.008)	(0.020)	(0.011)
Treatment × 2012	-0.035***	-0.028***	-0.087**	-0.090**	-0.021**	-0.019**	0.018	0.012
	(0.014)	(0.011)	(0.041)	(0.039)	(0.010)	(0.009)	(0.028)	(0.015)
Treatment × 2014	-0.049***	-0.038***	-0.108***	-0.100***	-0.030***	-0.027***	-0.027	-0.015
	(0.013)	(0.010)	(0.039)	(0.037)	(0.011)	(0.010)	(0.034)	(0.018)
Treatment × 2016	-0.002	-0.000	-0.010	-0.012	-0.001	-0.001	0.028	0.017
	(0.013)	(0.010)	(0.038)	(0.036)	(0.011)	(0.010)	(0.029)	(0.016)
Treatment × 2018	-0.040***	-0.032***	-0.096**	-0.089**	-0.025**	-0.022**	0.013	0.008
	(0.013)	(0.010)	(0.038)	(0.036)	(0.010)	(0.010)	(0.029)	(0.015)
Individual's age (years)		-0.001***						
		(0.000)						
Individual is female		0.003		0.001		0.006***		0.005
		(0.002)		(0.007)		(0.002)		(0.005)
Individual's education (years)		-0.001**		-0.018***		-0.000		0.001*
		(0.001)		(0.003)		(0.000)		(0.001)
Household size		0.005**		-0.019**		-0.002		0.004
		(0.002)		(0.009)		(0.001)		(0.003)
Ln(consumption)		-0.092***		0.201*		0.023		-0.061**
		(0.028)		(0.117)		(0.017)		(0.026)
Lives in ger		0.003		0.022*		0.001		-0.005
		(0.003)		(0.011)		(0.003)		(0.007)
Private boiler		0.059**		0.116		0.227***		-0.008
		(0.029)		(0.081)		(0.039)		(0.012)
Electric heater		-0.019		-0.126**		-0.000		0.236***
		(0.018)		(0.062)		(0.012)		(0.012)
Traditional stove		0.055*		0.106		0.221***		0.219
		(0.029)		(0.080)		(0.037)		(0.000)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo-R^2	0.02	0.10	0.03	0.05	0.03	0.03	0.03	0.05
N	21,985	21,985	6,160	6,160	14,233	14,233	1,592	1,592

Notes: Standard errors, clustered at the household level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is individuals living in house, male and using regular heater for residential heating; the reference year is 2010. Columns 1,3,5 and 7 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2,4,6 and 8 add individual–specific controls to the specification, including the type of the residence and heating sources in residence.

Table A.7: **Regression results of DiD models of the probability of illness: categorical education**

Variable name	All age groups combined (1)	(2)	Children (under 14 years) (3)	(4)	Working age adults (15-60 years) (5)	(6)	Older adults (over 60 years) (7)	(8)
Treatment	0.030***	0.018	0.050*	-0.021	0.030***	0.031	0.018	0.083
	(0.012)	(0.022)	(0.026)	(0.033)	(0.011)	(0.022)	(0.052)	(0.107)
2012	0.043***	0.070***	0.064**	0.002	0.041***	0.096***	0.008	0.129**
	(0.012)	(0.017)	(0.028)	(0.045)	(0.012)	(0.015)	(0.048)	(0.060)
2014	0.044***	0.073***	0.102***	0.033	0.035***	0.088***	-0.042	0.064
	(0.013)	(0.017)	(0.030)	(0.045)	(0.013)	(0.015)	(0.051)	(0.057)
2016	0.011	0.020*	0.054**	0.028	-0.003	0.013	0.013	0.043
	(0.011)	(0.012)	(0.026)	(0.027)	(0.010)	(0.010)	(0.055)	(0.056)
2018	0.071***	0.086***	0.105***	0.066**	0.053***	0.085***	0.069	0.137**
	(0.013)	(0.014)	(0.027)	(0.032)	(0.013)	(0.014)	(0.051)	(0.054)
Treatment × 2012	-0.060***	-0.062***	-0.098***	-0.108***	-0.053***	-0.055***	0.002	-0.021
	(0.015)	(0.015)	(0.034)	(0.034)	(0.015)	(0.015)	(0.066)	(0.068)
Treatment × 2014	-0.058***	-0.065***	-0.117***	-0.116***	-0.050***	-0.054***	0.026	0.009
	(0.016)	(0.016)	(0.037)	(0.037)	(0.016)	(0.016)	(0.067)	(0.069)
Treatment × 2016	0.008	-0.001	-0.003	-0.008	0.005	0.000	0.002	0.009
	(0.015)	(0.015)	(0.034)	(0.034)	(0.014)	(0.014)	(0.072)	(0.072)
Treatment × 2018	-0.048***	-0.054***	-0.109***	-0.108***	-0.026	-0.032*	-0.013	-0.027
	(0.016)	(0.017)	(0.034)	(0.034)	(0.017)	(0.017)	(0.069)	(0.070)
Individual's age (years)		0.002***						
		(0.000)						
Individual is female		0.017***		-0.002		0.023***		0.025
		(0.004)		(0.008)		(0.004)		(0.019)
Primary school		-0.053***		-0.083***		0.091***		0.193***
		(0.009)		(0.012)		(0.018)		(0.067)
Secondary school		-0.068***		-0.080***		0.079***		0.160**
		(0.012)		(0.029)		(0.011)		(0.067)
High school		-0.081***		-0.156***		0.081***		0.153**
		(0.012)		(0.030)		(0.010)		(0.064)
Vocational degree		-0.081***		-0.209***		0.091***		0.162**
		(0.014)		(0.035)		(0.011)		(0.066)
Bachelor		-0.099***		0.000		0.070***		0.139*
		(0.015)		(0.000)		(0.012)		(0.074)
Master		-0.074***		0.000		0.098***		0.092
		(0.019)		(0.000)		(0.016)		(0.091)
PhD		-0.058*		-0.288***		0.130***		0.182*
		(0.034)		(0.053)		(0.035)		(0.104)
Household size		0.005		-0.023**		0.012***		0.030***
		(0.004)		(0.011)		(0.003)		(0.011)
Ln(consumption)		-0.119**		0.235*		-0.216***		-0.379***
		(0.049)		(0.137)		(0.038)		(0.125)
Lives in ger		0.004		0.027**		-0.001		-0.040
		(0.006)		(0.012)		(0.006)		(0.028)
Private boiler		0.030		0.096***		0.015		-0.093
		(0.023)		(0.032)		(0.023)		(0.112)
Electric heater		-0.017		-0.096***		0.005		0.186
		(0.023)		(0.031)		(0.030)		(0.118)
Traditional stove		0.014		0.067***		-0.003		-0.055
		(0.020)		(0.024)		(0.020)		(0.103)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.01	0.03	0.02	0.03	0.01	0.02	0.04	0.06
N	21,985	21,985	6,160	6,160	14,233	14,233	1,592	1,592

Notes: Standard errors, clustered at the household level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is individuals living in house, male and using regular heater for residential heating; the reference year is 2010. Columns 1,3,5 and 7 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2,4,6 and 8 add individual–specific controls to the specification, including the type of the residence and heating sources in residence.

Table A.8: **Regression results of DiD models of the probability of having respiratory illness: categorical education**

	All age groups combined		Children (under 14 years)		Working age adults (15-60 years)		Older adults (over 60 years)	
Variable name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	0.020**	-0.008	0.042*	-0.015	0.014**	-0.003	-0.019	-0.027
	(0.008)	(0.009)	(0.024)	(0.032)	(0.007)	(0.006)	(0.029)	(0.027)
2012	0.023***	0.043***	0.046*	-0.014	0.017***	0.010	-0.009	0.035
	(0.008)	(0.012)	(0.025)	(0.041)	(0.006)	(0.009)	(0.028)	(0.031)
2014	0.040***	0.061***	0.102***	0.036	0.021***	0.016*	-0.007	0.027
	(0.010)	(0.012)	(0.029)	(0.043)	(0.008)	(0.009)	(0.029)	(0.031)
2016	0.016**	0.018**	0.048**	0.023	0.002	0.000	-0.011	0.001
	(0.008)	(0.008)	(0.024)	(0.025)	(0.005)	(0.005)	(0.029)	(0.029)
2018	0.043***	0.052***	0.091***	0.054*	0.024***	0.021***	-0.015	0.005
	(0.009)	(0.010)	(0.025)	(0.029)	(0.008)	(0.008)	(0.026)	(0.026)
Treatment × 2012	-0.029***	-0.027**	-0.072**	-0.082***	-0.018**	-0.017*	0.022	0.014
	(0.011)	(0.011)	(0.032)	(0.032)	(0.009)	(0.009)	(0.035)	(0.035)
Treatment × 2014	-0.045***	-0.045***	-0.106***	-0.104***	-0.027***	-0.028***	-0.011	-0.015
	(0.012)	(0.012)	(0.035)	(0.035)	(0.010)	(0.010)	(0.035)	(0.035)
Treatment × 2016	0.009	0.009	0.012	0.008	0.005	0.004	0.036	0.033
	(0.011)	(0.011)	(0.032)	(0.032)	(0.008)	(0.008)	(0.037)	(0.038)
Treatment × 2018	-0.038***	-0.039***	-0.093***	-0.091***	-0.024**	-0.024**	0.017	0.015
	(0.012)	(0.012)	(0.032)	(0.032)	(0.010)	(0.010)	(0.033)	(0.033)
Individual's age (years)		-0.001***						
		(0.000)						
Individual is female		0.004		0.001		0.008***		0.009
		(0.003)		(0.008)		(0.002)		(0.009)
Primary school		-0.047***		-0.077***		0.031***		0.049***
		(0.007)		(0.011)		(0.011)		(0.017)
Secondary school		-0.055***		-0.118***		0.019***		0.056***
		(0.007)		(0.019)		(0.006)		(0.017)
High school		-0.053***		-0.128***		0.015***		0.058***
		(0.008)		(0.028)		(0.005)		(0.018)
Vocational degree		-0.047***		-0.175***		0.011**		0.081***
		(0.009)		(0.034)		(0.005)		(0.020)
Bachelor		-0.053***		0.000		0.012*		0.055**
		(0.010)		(0.000)		(0.007)		(0.024)
Master		-0.040***		0.000		0.016*		0.038
		(0.012)		(0.000)		(0.010)		(0.023)
PhD		-0.003		-0.251***		0.044*		0.109*
		(0.025)		(0.049)		(0.026)		(0.065)
Household size		0.005**		-0.021**		-0.002		0.008
		(0.002)		(0.010)		(0.002)		(0.005)
Ln(consumption)		-0.100***		0.230*		0.021		-0.122**
		(0.032)		(0.130)		(0.022)		(0.061)
Lives in ger		0.004		0.023*		0.000		-0.011
		(0.005)		(0.012)		(0.004)		(0.013)
Private boiler		0.031***		0.065**		0.025***		-0.021
		(0.011)		(0.031)		(0.008)		(0.015)
Electric heater		-0.022		-0.079***		-0.001		0.066
		(0.017)		(0.027)		(0.021)		(0.063)
Traditional stove		0.025***		0.054**		0.017***		0.019
		(0.007)		(0.024)		(0.003)		(0.014)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.01	0.04	0.02	0.03	0.01	0.01	0.01	0.02
N	21,985	21,985	6,160	6,160	14,233	14,233	1,592	1,592

Notes: Standard errors, clustered at the household level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is individuals living in house, male and using regular heater for residential heating; the reference year is 2010. Columns 1,3,5 and 7 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2,4,6 and 8 add individual–specific controls to the specification, including the type of the residence and heating sources in residence.

Table A.9: **Regression results of DiD models of the probability of having overall and respiratory illness: age in quadratic form**

	Overall illness		Respiratory illness	
Variable name	(1)	(2)	(3)	(4)
Treatment	0.030***	0.016	0.020**	-0.011
	(0.012)	(0.022)	(0.008)	(0.009)
2012	0.043***	0.040**	0.023***	0.024**
	(0.012)	(0.017)	(0.008)	(0.012)
2014	0.044***	0.038**	0.040***	0.039***
	(0.013)	(0.017)	(0.010)	(0.012)
2016	0.011	0.011	0.016**	0.014*
	(0.011)	(0.012)	(0.008)	(0.008)
2018	0.071***	0.067***	0.043***	0.043***
	(0.013)	(0.014)	(0.009)	(0.010)
Treatment × 2012	-0.060***	-0.068***	-0.029***	-0.033***
	(0.015)	(0.015)	(0.011)	(0.011)
Treatment × 2014	-0.058***	-0.067***	-0.045***	-0.048***
	(0.016)	(0.016)	(0.012)	(0.012)
Treatment × 2016	0.008	-0.001	0.009	0.008
	(0.015)	(0.015)	(0.011)	(0.011)
Treatment × 2018	-0.048***	-0.055***	-0.038***	-0.042***
	(0.016)	(0.016)	(0.012)	(0.012)
Individual's age (age^2)		0.000***		-0.000
		(0.000)		(0.000)
Individual is female		0.018***		0.006**
		(0.004)		(0.003)
Individual's education (years)		-0.007***		-0.006***
		(0.001)		(0.001)
Household size		-0.005		-0.002
		(0.004)		(0.002)
Ln(consumption)		0.030		0.000
		(0.048)		(0.032)
Lives in ger		0.005		0.004
		(0.006)		(0.005)
Private boiler		0.032		0.033***
		(0.023)		(0.011)
Electric heater		-0.016		-0.020
		(0.023)		(0.017)
Traditional stove		0.015		0.024***
		(0.019)		(0.006)
District fixed effects	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes
Adjusted-R^2	0.01	0.03	0.01	0.04
N	21,985	21,985	21,985	21,985

Notes: Standard errors, clustered at the household level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is individuals living in house, male and using regular heater for residential heating; the reference year is 2010. Columns 1 and 3 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2 and 4 add individual–specific controls to the specification, including the type of the residence and heating sources in residence.

Table A.10: **Regression results of DiD models of the impact of subsidy on the level value of household monthly electricity expenditures**

	Winter months			Non-winter months		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	-3.615**	-1.841*	-3.503***	-1.789**	-0.541	3.965*
	(0.984)	(0.848)	(0.709)	(0.510)	(0.556)	(1.641)
2012	-0.309	-1.758**	-1.372*	-0.192	-1.576*	-1.216
	(0.776)	(0.548)	(0.566)	(0.622)	(0.673)	(0.632)
2014	-1.981***	-3.705***	-3.186***	-2.482***	-3.914***	-3.465***
	(0.313)	(0.437)	(0.326)	(0.195)	(0.436)	(0.329)
2016	0.517	-0.680	-0.297	-0.401	-1.549**	-1.281*
	(0.603)	(0.420)	(0.398)	(0.619)	(0.534)	(0.563)
2018	-0.824	-2.358***	-1.976***	-1.499**	-2.748***	-2.452***
	(0.415)	(0.322)	(0.213)	(0.473)	(0.126)	(0.136)
Treatment × 2012	1.947*	2.922**	2.151**	0.999	2.036*	1.349
	(0.945)	(0.949)	(0.779)	(1.012)	(0.938)	(1.200)
Treatment × 2014	3.091**	4.191***	2.207*	2.148**	3.118**	2.054**
	(1.037)	(1.037)	(0.993)	(0.767)	(0.818)	(0.710)
Treatment × 2016	2.331**	2.720**	1.526	1.602***	2.502***	1.933***
	(0.853)	(0.823)	(0.864)	(0.277)	(0.257)	(0.342)
Treatment × 2018	4.013***	4.646***	2.666***	4.383***	5.019***	3.048***
	(0.799)	(0.868)	(0.600)	(0.573)	(0.447)	(0.434)
Household head's age (years)		0.044**	0.049***		0.030***	0.037***
		(0.011)	(0.011)		(0.004)	(0.005)
Household head is female		-0.402	-0.437*		-0.063	-0.122
		(0.272)	(0.204)		(0.129)	(0.169)
Household head's education (years)		0.268***	0.175***		0.190***	0.145***
		(0.024)	(0.026)		(0.015)	(0.022)
Household head is married		0.893***	0.845**		1.107***	0.627**
		(0.163)	(0.253)		(0.173)	(0.194)
Share of working members		0.794**	0.592**		0.176	0.152
		(0.293)	(0.204)		(0.483)	(0.490)
Household size		0.727***	0.809***		0.710***	0.803***
		(0.110)	(0.093)		(0.121)	(0.106)
Ln(income)		1.144***	0.901***		1.133***	0.895***
		(0.234)	(0.182)		(0.233)	(0.174)
Lives in ger		-3.982***	-2.387***		-3.677***	-2.076***
		(0.353)	(0.191)		(0.328)	(0.066)
Private boiler			3.467***			-2.491*
			(0.774)			(1.005)
Electric heater			48.831***			34.538***
			(5.045)			(5.088)
Traditional stove			0.843			-5.794***
			(0.519)			(1.416)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.01	0.10	0.40	0.02	0.10	0.38
Number of households	5,766	5,766	5,766	7,975	7,975	7,975

Notes: Robust standard errors, clustered at the district level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is households living in house, have male & unmarried household head and using regular heater for residential heating; the reference year is 2010. Columns 1 and 4 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2 and 5 add household–specific controls to the specification, including the type of residence. The preferred model results in Columns 3 and 6 further add heating sources in the residence to the specification.

Table A.11: **Regression results of DiD models of the impact of subsidy on household monthly per capita electricity expenditures**

	Winter months			Non-winter months		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	-0.422***	-0.267**	-0.331**	-0.326***	-0.212***	-0.093
	(0.061)	(0.086)	(0.100)	(0.019)	(0.028)	(0.080)
2012	-0.006	-0.228**	-0.217**	0.008	-0.219***	-0.206***
	(0.053)	(0.073)	(0.070)	(0.048)	(0.046)	(0.045)
2014	-0.045	-0.309***	-0.293***	-0.073**	-0.332***	-0.316***
	(0.042)	(0.056)	(0.053)	(0.022)	(0.051)	(0.048)
2016	0.118**	-0.110*	-0.098	0.090**	-0.149**	-0.139**
	(0.031)	(0.054)	(0.050)	(0.030)	(0.046)	(0.045)
2018	0.036	-0.234**	-0.222**	-0.042**	-0.278***	-0.266***
	(0.034)	(0.062)	(0.059)	(0.012)	(0.044)	(0.042)
Treatment × 2012	0.131	0.237*	0.217*	0.129	0.232**	0.208**
	(0.080)	(0.098)	(0.092)	(0.073)	(0.067)	(0.078)
Treatment × 2014	0.214**	0.278**	0.221**	0.155***	0.250***	0.214***
	(0.064)	(0.074)	(0.073)	(0.019)	(0.047)	(0.046)
Treatment × 2016	0.183**	0.219**	0.187*	0.164***	0.233***	0.213***
	(0.053)	(0.083)	(0.082)	(0.023)	(0.033)	(0.035)
Treatment × 2018	0.229***	0.300**	0.244**	0.281***	0.348***	0.284***
	(0.039)	(0.080)	(0.073)	(0.034)	(0.053)	(0.057)
Household head's age (years)		0.006***	0.006***		0.005***	0.006***
		(0.001)	(0.001)		(0.000)	(0.000)
Household head is female		0.009	0.008		-0.004	-0.005
		(0.029)	(0.034)		(0.027)	(0.028)
Household head's education (years)		0.011***	0.009**		0.012***	0.010***
		(0.002)	(0.002)		(0.001)	(0.002)
Household head is married		-0.196***	-0.197***		-0.221***	-0.235***
		(0.023)	(0.027)		(0.029)	(0.031)
Share of working members		0.207***	0.201***		0.152***	0.152***
		(0.020)	(0.021)		(0.037)	(0.036)
Ln(income)		0.185***	0.177***		0.184***	0.174***
		(0.013)	(0.013)		(0.024)	(0.022)
Lives in ger		-0.195***	-0.153***		-0.164***	-0.114***
		(0.015)	(0.012)		(0.012)	(0.007)
Private boiler			0.070			-0.043
			(0.071)			(0.062)
Electric heater			1.480***			1.069***
			(0.115)			(0.120)
Traditional stove			0.043			-0.158*
			(0.054)			(0.073)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.06	0.21	0.27	0.05	0.20	0.26
Number of households	5,766	5,766	5,766	7,975	7,975	7,975

Notes: Robust standard errors, clustered at the district level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is households living in house, have male & unmarried household head and using regular heater for residential heating; the reference year is 2010. Columns 1 and 4 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2 and 5 add household–specific controls to the specification, including the type of residence. The preferred model results in Columns 3 and 6 further add heating sources in the residence to the specification.

Table A.12: **Regression results of DiD models of the impact of subsidy on household monthly electricity expenditures: OECD equivalence scale adjusted**

	Winter months			Non-winter months		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	-0.368***	-0.240**	-0.340**	-0.265***	-0.161***	-0.029
	(0.058)	(0.066)	(0.088)	(0.015)	(0.023)	(0.062)
2012	-0.014	-0.124**	-0.111**	0.000	-0.107**	-0.094*
	(0.036)	(0.046)	(0.043)	(0.042)	(0.040)	(0.040)
2014	-0.063	-0.200***	-0.183***	-0.091***	-0.214***	-0.199***
	(0.036)	(0.038)	(0.035)	(0.016)	(0.032)	(0.029)
2016	0.108***	0.003	0.015	0.072	-0.030	-0.020
	(0.027)	(0.026)	(0.023)	(0.036)	(0.037)	(0.037)
2018	0.021	-0.104**	-0.091**	-0.033**	-0.133***	-0.121***
	(0.023)	(0.030)	(0.027)	(0.011)	(0.021)	(0.019)
Treatment × 2012	0.133*	0.201**	0.178**	0.122	0.183**	0.159*
	(0.056)	(0.068)	(0.062)	(0.067)	(0.063)	(0.073)
Treatment × 2014	0.199**	0.250***	0.191**	0.141***	0.196***	0.160***
	(0.055)	(0.058)	(0.056)	(0.024)	(0.038)	(0.038)
Treatment × 2016	0.175**	0.198**	0.163*	0.148***	0.188***	0.166***
	(0.056)	(0.065)	(0.066)	(0.022)	(0.024)	(0.025)
Treatment × 2018	0.240***	0.278***	0.219***	0.262***	0.292***	0.229***
	(0.032)	(0.051)	(0.044)	(0.025)	(0.036)	(0.041)
Household head's age (years)		0.003**	0.003**		0.002***	0.002***
		(0.001)	(0.001)		(0.000)	(0.000)
Household head is female		0.020	0.019		0.008	0.007
		(0.022)	(0.026)		(0.020)	(0.021)
Household head's education (years)		0.014***	0.012***		0.014***	0.012***
		(0.002)	(0.002)		(0.002)	(0.002)
Household head is married		-0.065**	-0.065*		-0.084***	-0.098***
		(0.020)	(0.026)		(0.019)	(0.022)
Share of working members		0.115***	0.107***		0.077*	0.075*
		(0.012)	(0.013)		(0.034)	(0.034)
Ln(income)		0.083***	0.074***		0.075***	0.066***
		(0.012)	(0.012)		(0.016)	(0.015)
Lives in ger		-0.211***	-0.166***		-0.183***	-0.131***
		(0.014)	(0.011)		(0.012)	(0.007)
Private boiler			0.138			-0.038
			(0.070)			(0.049)
Electric heater			1.520***			1.042***
			(0.111)			(0.108)
Traditional stove			0.079			-0.171**
			(0.057)			(0.061)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.06	0.13	0.21	0.05	0.12	0.21
Number of households	5,766	5,766	5,766	7,975	7,975	7,975

Notes: Robust standard errors, clustered at the district level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is households living in house, have male & unmarried household head and using regular heater for residential heating; the reference year is 2010. Columns 1 and 4 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2 and 5 add household–specific controls to the specification, including the type of residence. The preferred model results in Columns 3 and 6 further add heating sources in the residence to the specification.

Table A.13: **Regression results of DiD models of the impact of subsidy on household monthly electricity expenditures: square root of family size scale adjusted**

	Winter months			Non-winter months		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	-0.359***	-0.228**	-0.330**	-0.252***	-0.142***	-0.013
	(0.060)	(0.064)	(0.084)	(0.016)	(0.023)	(0.047)
2012	-0.026	-0.105**	-0.094*	-0.013	-0.091*	-0.078*
	(0.032)	(0.039)	(0.037)	(0.040)	(0.038)	(0.038)
2014	-0.089**	-0.189***	-0.174***	-0.117***	-0.207***	-0.192***
	(0.033)	(0.034)	(0.033)	(0.013)	(0.028)	(0.025)
2016	0.081**	0.014	0.026	0.042	-0.025	-0.016
	(0.026)	(0.022)	(0.020)	(0.039)	(0.036)	(0.036)
2018	-0.002	-0.093***	-0.081***	-0.058**	-0.123***	-0.112***
	(0.018)	(0.021)	(0.018)	(0.017)	(0.014)	(0.012)
Treatment × 2012	0.144**	0.199**	0.175**	0.123	0.172**	0.148*
	(0.047)	(0.058)	(0.052)	(0.066)	(0.063)	(0.073)
Treatment × 2014	0.202**	0.242***	0.182**	0.146***	0.188***	0.151**
	(0.060)	(0.059)	(0.057)	(0.025)	(0.037)	(0.039)
Treatment × 2016	0.185**	0.195**	0.158*	0.148***	0.176***	0.154***
	(0.059)	(0.064)	(0.066)	(0.024)	(0.024)	(0.024)
Treatment × 2018	0.245***	0.273***	0.213***	0.268***	0.285***	0.221***
	(0.038)	(0.049)	(0.041)	(0.023)	(0.031)	(0.035)
Household head's age (years)		0.005***	0.005***		0.004***	0.004***
		(0.001)	(0.001)		(0.000)	(0.000)
Household head is female		-0.006	-0.007		-0.009	-0.010
		(0.018)	(0.023)		(0.018)	(0.019)
Household head's education (years)		0.014***	0.011***		0.014***	0.012***
		(0.001)	(0.002)		(0.001)	(0.001)
Household head is married		-0.032	-0.032		-0.042*	-0.055**
		(0.020)	(0.025)		(0.018)	(0.020)
Share of working members		0.137***	0.129***		0.108**	0.105**
		(0.014)	(0.014)		(0.032)	(0.032)
Ln(income)		0.059***	0.052***		0.050**	0.042**
		(0.011)	(0.011)		(0.013)	(0.012)
Lives in ger		-0.222***	-0.176***		-0.195***	-0.142***
		(0.012)	(0.009)		(0.013)	(0.007)
Private boiler			0.157*			-0.028
			(0.072)			(0.037)
Electric heater			1.507***			1.037***
			(0.110)			(0.098)
Traditional stove			0.080			-0.170**
			(0.059)			(0.048)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.06	0.13	0.23	0.05	0.12	0.22
Number of households	5,766	5,766	5,766	7,975	7,975	7,975

Notes: Robust standard errors, clustered at the district level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is households living in house, have male & unmarried household head and using regular heater for residential heating; the reference year is 2010. Columns 1 and 4 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2 and 5 add household–specific controls to the specification, including the type of residence. The preferred model results in Columns 3 and 6 further add heating sources in the residence to the specification.

Table A.14: **Regression results of DiD models of the impact of subsidy on household monthly electricity expenditures: with categorical education**

	Winter months			Non-winter months		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	-0.296**	-0.208**	-0.338**	-0.177***	-0.112***	0.002
	(0.075)	(0.069)	(0.100)	(0.024)	(0.023)	(0.042)
2012	-0.045	-0.119**	-0.105**	-0.034	-0.113**	-0.101**
	(0.038)	(0.031)	(0.031)	(0.033)	(0.033)	(0.032)
2014	-0.133***	-0.219***	-0.200***	-0.161***	-0.242***	-0.227***
	(0.032)	(0.028)	(0.028)	(0.006)	(0.020)	(0.016)
2016	0.043	-0.025	-0.013	-0.006	-0.077	-0.068
	(0.040)	(0.021)	(0.021)	(0.052)	(0.039)	(0.040)
2018	-0.040	-0.126***	-0.113***	-0.073	-0.153***	-0.143***
	(0.030)	(0.015)	(0.013)	(0.037)	(0.018)	(0.018)
Treatment × 2012	0.156***	0.204***	0.179***	0.116	0.175**	0.151*
	(0.034)	(0.044)	(0.038)	(0.060)	(0.057)	(0.065)
Treatment × 2014	0.190**	0.248***	0.184**	0.137**	0.192***	0.157***
	(0.062)	(0.059)	(0.056)	(0.036)	(0.037)	(0.036)
Treatment × 2016	0.186*	0.210**	0.170*	0.132***	0.190***	0.168***
	(0.078)	(0.069)	(0.070)	(0.033)	(0.029)	(0.026)
Treatment × 2018	0.261***	0.296***	0.234***	0.255***	0.297***	0.235***
	(0.058)	(0.056)	(0.047)	(0.031)	(0.031)	(0.035)
Household head's age (years)		0.003**	0.003**		0.002***	0.002***
		(0.001)	(0.001)		(0.000)	(0.000)
Household head is female		-0.000	-0.001		-0.006	-0.007
		(0.016)	(0.019)		(0.013)	(0.014)
Primary school		0.089	0.082		-0.078	-0.055
		(0.069)	(0.071)		(0.046)	(0.038)
Secondary school		0.157	0.157		0.013	0.038
		(0.109)	(0.111)		(0.046)	(0.033)
High school		0.188*	0.182		0.052	0.072**
		(0.090)	(0.093)		(0.038)	(0.027)
Vocational degree		0.215*	0.205*		0.075	0.087**
		(0.091)	(0.093)		(0.038)	(0.027)
Bachelor		0.234*	0.207		0.132**	0.134***
		(0.103)	(0.105)		(0.043)	(0.027)
Master		0.236*	0.201		0.106*	0.112**
		(0.093)	(0.101)		(0.046)	(0.040)
PhD		0.334**	0.299**		0.143**	0.152**
		(0.090)	(0.099)		(0.045)	(0.044)
Household head is married		0.083***	0.082**		0.078***	0.063***
		(0.019)	(0.024)		(0.010)	(0.013)
Share of working members		0.044**	0.038**		0.023	0.022
		(0.012)	(0.011)		(0.031)	(0.032)
Household size		0.057***	0.059***		0.056***	0.059***
		(0.006)	(0.005)		(0.006)	(0.006)
Ln(income)		0.071***	0.064***		0.069***	0.062***
		(0.012)	(0.012)		(0.012)	(0.011)
Lives in ger		-0.228***	-0.181***		-0.196***	-0.144***
		(0.015)	(0.009)		(0.015)	(0.010)
Private boiler			0.197**			-0.011
			(0.071)			(0.027)
Electric heater			1.506***			1.008***
			(0.104)			(0.103)
Traditional stove			0.106			-0.156**
			(0.067)			(0.040)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.04	0.17	0.26	0.03	0.17	0.27
Number of households	5,766	5,766	5,766	7,975	7,975	7,975

Notes: Robust standard errors, clustered at the district level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is households living in house, have male & unmarried household head and using regular heater for residential heating; the reference year is 2010. Columns 1 and 4 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2 and 5 add household–specific controls to the specification, including the type of residence. The preferred model results in Columns 3 and 6 further add heating sources in the residence to the specification.

Table A.15: **Regression results of DiD models of the impact of subsidy on household monthly electricity expenditures: age in quadratic form**

	Winter months			Non-winter months		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	-0.296**	-0.208**	-0.339**	-0.177***	-0.117***	0.004
	(0.075)	(0.067)	(0.099)	(0.024)	(0.021)	(0.039)
2012	-0.045	-0.125**	-0.114**	-0.034	-0.119**	-0.107**
	(0.038)	(0.032)	(0.031)	(0.033)	(0.035)	(0.035)
2014	-0.133***	-0.226***	-0.210***	-0.161***	-0.247***	-0.233***
	(0.032)	(0.029)	(0.028)	(0.006)	(0.020)	(0.017)
2016	0.043	-0.026	-0.014	-0.006	-0.074	-0.066
	(0.040)	(0.019)	(0.020)	(0.052)	(0.039)	(0.040)
2018	-0.040	-0.127***	-0.116***	-0.073	-0.150***	-0.140***
	(0.030)	(0.013)	(0.012)	(0.037)	(0.017)	(0.017)
Treatment × 2012	0.156***	0.209***	0.185***	0.116	0.180**	0.156*
	(0.034)	(0.046)	(0.040)	(0.060)	(0.058)	(0.066)
Treatment × 2014	0.190**	0.254***	0.194**	0.137**	0.198***	0.162***
	(0.062)	(0.059)	(0.057)	(0.036)	(0.034)	(0.034)
Treatment × 2016	0.186*	0.213**	0.176*	0.132***	0.188***	0.167***
	(0.078)	(0.068)	(0.070)	(0.033)	(0.029)	(0.026)
Treatment × 2018	0.261***	0.299***	0.239***	0.255***	0.296***	0.234***
	(0.058)	(0.056)	(0.048)	(0.031)	(0.030)	(0.032)
Household head's age (age^2)		0.000**	0.000**		0.000***	0.000***
		(0.000)	(0.000)		(0.000)	(0.000)
Household head is female		0.004	0.003		-0.003	-0.004
		(0.016)	(0.019)		(0.014)	(0.015)
Household head's education (years)		0.012***	0.009***		0.012***	0.010***
		(0.001)	(0.002)		(0.001)	(0.001)
Household head is married		0.086***	0.085**		0.080***	0.065***
		(0.019)	(0.024)		(0.011)	(0.013)
Share of working members		0.044**	0.038**		0.021	0.020
		(0.012)	(0.011)		(0.032)	(0.033)
Household size		0.058***	0.060***		0.056***	0.059***
		(0.006)	(0.005)		(0.006)	(0.006)
Ln(income)		0.071***	0.064***		0.070***	0.062***
		(0.013)	(0.012)		(0.012)	(0.011)
Lives in ger		-0.230***	-0.183***		-0.199***	-0.147***
		(0.015)	(0.009)		(0.015)	(0.009)
Private boiler			0.201**			-0.016
			(0.070)			(0.026)
Electric heater			1.504***			1.003***
			(0.104)			(0.101)
Traditional stove			0.109			-0.161**
			(0.066)			(0.041)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.04	0.17	0.26	0.03	0.17	0.27
Number of households	5,766	5,766	5,766	7,975	7,975	7,975

Notes: Robust standard errors, clustered at the district level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is households living in house, have male & unmarried household head and using regular heater for residential heating; the reference year is 2010. Columns 1 and 4 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2 and 5 add household–specific controls to the specification, including the type of residence. The preferred model results in Columns 3 and 6 further add heating sources in the residence to the specification.

Table A.16: **Regression results of DiD models of the impact of subsidy on household monthly electricity expenditures: year-round**

Variable	(1)	(2)	(3)
Treatment	-0.224***	-0.152***	-0.127**
	(0.043)	(0.033)	(0.043)
2012	-0.038	-0.121***	-0.109***
	(0.026)	(0.024)	(0.023)
2014	-0.149***	-0.237***	-0.223***
	(0.013)	(0.018)	(0.015)
2016	0.017	-0.051	-0.041
	(0.043)	(0.027)	(0.028)
2018	-0.053	-0.135***	-0.124***
	(0.033)	(0.010)	(0.011)
Treatment × 2012	0.131**	0.190**	0.165**
	(0.046)	(0.051)	(0.055)
Treatment × 2014	0.158**	0.218***	0.172***
	(0.044)	(0.038)	(0.039)
Treatment × 2016	0.153**	0.196***	0.167***
	(0.041)	(0.030)	(0.033)
Treatment × 2018	0.253***	0.293***	0.230***
	(0.040)	(0.030)	(0.027)
Household head's age (years)		0.002***	0.003***
		(0.000)	(0.000)
Household head is female		-0.005	-0.006
		(0.010)	(0.009)
Household head's education (years)		0.012***	0.010***
		(0.001)	(0.001)
Household head is married		0.080***	0.071***
		(0.008)	(0.009)
Share of working members		0.029	0.026
		(0.020)	(0.020)
Household size		0.057***	0.059***
		(0.006)	(0.005)
Ln(income)		0.070***	0.063***
		(0.011)	(0.010)
Lives in ger		-0.211***	-0.161***
		(0.011)	(0.008)
Private boiler			0.064
			(0.041)
Electric heater			1.194***
			(0.104)
Traditional stove			-0.057
			(0.038)
District fixed effects	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes
Adjusted R^2	0.03	0.17	0.26
Number of households	13,741	13,741	13,741

Notes: Robust standard errors, clustered at the district level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is households living in house, have male & unmarried household head and using regular heater for residential heating; the reference year is 2010. Columns 1 runs the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2 adds household–specific controls to the specification, including the type of residence. The preferred model results in Columns 3 further adds heating sources in the residence to the specification.

Table A.17: **Regression results of DiD models of the impact of subsidy on household monthly electricity expenditures: 2012 as the treatment year**

	Winter months			Non-winter months		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	-0.282**	-0.190*	-0.402**	-0.163***	-0.102***	0.089
	(0.087)	(0.078)	(0.112)	(0.023)	(0.017)	(0.071)
2012	-0.028	-0.063*	-0.067**	-0.022	-0.064*	-0.062*
	(0.040)	(0.027)	(0.026)	(0.033)	(0.030)	(0.031)
Treatment × 2012	0.144***	0.184***	0.184***	0.106	0.150**	0.146*
	(0.034)	(0.041)	(0.032)	(0.058)	(0.056)	(0.064)
Household head's age (years)		0.002**	0.002**		0.002*	0.002*
		(0.001)	(0.001)		(0.001)	(0.001)
Household head is female		0.021	0.025		-0.032	-0.032
		(0.040)	(0.039)		(0.030)	(0.028)
Household head's education (years)		0.012**	0.012**		0.014***	0.012***
		(0.005)	(0.004)		(0.002)	(0.002)
Household head is married		0.083*	0.081		0.043	0.042
		(0.037)	(0.041)		(0.023)	(0.024)
Share of working members		0.113**	0.106**		0.010	0.012
		(0.032)	(0.034)		(0.019)	(0.019)
Household size		0.058***	0.059***		0.066***	0.065***
		(0.007)	(0.007)		(0.009)	(0.009)
Ln(income)		0.026**	0.027*		0.027*	0.027*
		(0.010)	(0.011)		(0.012)	(0.012)
Lives in ger		-0.249***	-0.255***		-0.198***	-0.181***
		(0.034)	(0.016)		(0.009)	(0.013)
Private boiler			0.065			-0.159**
			(0.178)			(0.058)
Electric heater			1.855***			0.267
			(0.293)			(0.206)
Traditional stove			0.225*			-0.212**
			(0.094)			(0.065)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.04	0.14	0.16	0.03	0.14	0.15
Number of households	2,102	2,102	2,102	3,021	3,021	3,021

Notes: Robust standard errors, clustered at the district level, are presented in the parentheses. * p <0.10, ** p <0.05, *** p <0.01. The reference group is households living in house, have male & unmarried household head and using regular heater for residential heating; the reference year is 2010. Columns 1 and 4 run the basic difference-in-differences model with district, month, and survey year fixed effects. Columns 2 and 5 add household–specific controls to the specification, including the type of residence. The preferred model results in Columns 3 and 6 further add heating sources in the residence to the specification.