Estimating Energy Price Elasticities when Salience is High: Residential Natural Gas Demand in Ukraine

by

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Abstract. Despite its importance for policy purposes (including climate policy and the energy transition), evidence about the price elasticity of natural gas demand in the residential sector is very limited and based on inference from situations with modest variation in prices. We focus on a locale and time when price changes were extreme and presumably salient to consumers, namely Ukraine between 2013 and 2017. We exploit the tariff reforms and detailed micro-level household consumption records to estimate the price elasticity of the demand for natural gas. To isolate behavior, attention is restricted to those households that made no structural energy-efficiency upgrades to their homes, and thus kept the stock of gas-using capital fixed. We further examine the short-run elasticity by restricting the sample to a few months before and after the tariff changes. Our results suggest that under extreme price changes, households *are* capable of reducing consumption, even without installing insulation or making any other structural modifications to their homes. The price elasticity is about -0.16. Wealthier households, people living in multifamily buildings, and heavy users have more inelastic demands. Households reduced consumption even when they received "subsidies," namely lump-sum government assistance, suggesting that when the price signal is sufficiently strong, lump-sum transfers have only a minimal effect on consumption. We also find some evidence that the stronger the salience, the stronger the responsiveness to price, although this effect is modest and may partly overlap with that of income or baseline consumption. Our data also suggest that the consumers with the lowest uptake of energy efficiency improvements might be those who—by necessity or through skills—are the most productive at reducing energy use through behaviors.

JEL Classification: D12 (Consumer Economics: Empirical Analysis); Q41 (Energy: Demand and Supply • Prices); Q48 (Energy: Government Policy); H31 (Fiscal Policies and Behavior of Economic Agents – Households)

Keywords: residential gas demand; energy transition; short-run price elasticity; tariff reforms; salience; fuel poverty.

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1. Introduction

At an average content of 53.07 kilograms of carbon dioxide per million British Thermal Units (BTUs), natural gas is generally regarded as the cleanest-burning fossil fuel.[2] In the US alone, it currently ranks as the most widely used fuel for space heating (OECD/IEA 2018) and its use for power generation has been increasingly steadily over recent years, just as coal-fired generation has been declining, due to a combination of market forces, technological innovation in extraction, and environmental concerns. At this time, gas-fired plants account for about one-third of power generation in the US,[3] and, depending on the area, for a much larger share during peak load times.

Similar trends have been observed in the European Union, which remains a net importer of natural gas.[4] The geopolitics of natural gas are complicated, as natural gas exporting countries have often been politically unstable or involved in conflicts, and delivering natural gas involves the construction of pipelines, sometimes from or through such nations. Reducing dependence on natural gas is thus part of a smooth transition to low-carbon, secure sources of energy.[5]

In this paper, we focus on residential demand for natural gas (for space and water heating, and cooking). In Ukraine, our study site, such demand accounts for 36% of total

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[2] See https://www.eia.gov/environment/emissions/co2_vol_mass.php.
[3] See https://www.eia.gov/todayinenergy/detail.php?id=34612.
[4] See https://ec.europa.eu/eurostat/statistics-explained/pdfscache/46126.pdf.
[5] See https://energytransition.org/.

consumption (OECD/IEA 2018).[6] We are interested in its responsiveness to price. Traditionally, this information is summarized into the (own) price elasticity of demand, a key parameter for predicting how demand would change if a tax on each unit of natural gas was introduced (or revised) to correct for the externalities associated with gas usage (such as a carbon tax), computing the loss of welfare associated with disruptions in supply, and understanding the extent of the rebound effect (Sorrell et al., 2009) following improvements in the energy efficiency (EE) of buildings.

Surprisingly, evidence about the price elasticity of natural gas demand from the residential sector is limited. Auffhammer and Rubin (2018) identify a total of nine studies from the US, the UK and Germany, uncovering demand functions ranging from almost inelastic (price elasticity -0.08; Metcalf and Hassett, 1999) to almost perfectly elastic (price elasticity -0.71; Metcalf and Hassett, 1999). Auffhammer and Rubin (2018) use a large panel from California and usage records from almost 6 million households, finding that the price elasticity falls in the range from -0.23 to -0.17 and varies across seasons and with household income.

Burke and Yang (2016) rely on a panel of national-level data from several countries, and find that while gas consumption as a whole is responsive to price, the demand for gas from the residential sector is inelastic in the short run. The estimated short-run price elasticity is -0.13, but this coefficient is statistically insignificant at the conventional levels. Burns (2017) examines aggregate data from the US and concludes that the demand is price-inelastic and getting more so over time.

[6] In 2016, 59% of the heat in Ukraine was produced from burning gas, while only 6% of the total consumption is for generating electricity (OECD/IEA 2018). In Ukraine combined heat and power, heat, and the electric power sector account for 33% of the total consumption of natural gas, the industrial sector for 10%, the residential sector for 36%, transportation for 5.5%, and the commercial, non-energy sector, own use and losses for the remaining 12%.

The identification of the price elasticity of demand does, of course, depend crucially on the variation in prices over time and across the units of observation. Auffhammer and Rubin (2018) appear to rely on price fluctuations well within 50% of the lowest price observed over 2010-2016; baseline prices (price in the first tier of consumption) and marginal prices generally exhibit coefficients of variation no greater than 0.20 (Auffhammer and Rubin, 2018, table 3).

When price changes are small, one wonders whether they are salient to people (Deryugina et al., 2019; Alberini et al., 2011). Salience refers to economic agents' ability to fully observe, retain and process the price of something, or changes in the price of something. Salience may be compromised by price labels that fail to report a portion of the price of the item, such as the sales tax eventually imposed on it (Chetty et al., 2009), by automatic billing schemes where charges go unnoticed (Finkelstein, 2009; Sexton, 2015), or by offering an incentive through a credit on the income tax rather than a rebate on the price of the good (Gallagher and Muehlegger, 2011).

In sum, how large must price changes be to be salient, or for any changes in demand to be appreciable? And how large should they be to create strong incentives to conservation, even in the presence of potentially offsetting income transfers and government assistance to households?

In this paper, we focus on a locale and time when price changes were extreme and salient to consumers, namely Ukraine between 2013 and 2017. From one month to the next (March 2015 to April 2015), the tariffs tripled, and by the subsequent month (May 2015), they were seven times as high as in March. The tariff hikes were accompanied by a restructuring of the tier system, and later (April 2016) by the complete removal of the block system.

We take advantage of the tariff scheme structure and reform, and the associated tariff shocks, to identify the short-run elasticity of residential gas demand in city of Uzhhorod in western Ukraine. Unlike other parts of Ukraine, where district heating may still be important,[7] the region around Uzhhorod, Transcarpathia, began to disconnect homes from district heating in 2005 and completed this process by 2012. By the beginning of our study period (January 2013), every dwelling had its own separate heating system, even in multifamily buildings, and was responsible for paying for its own consumption. Most people chose natural gas as their main heating fuel, taking advantage of existing infrastructure and low, and highly subsidized, residential natural gas prices.[8]

We ask three research questions. First, faced with massive tariff hikes, are people capable of reducing gas consumption? Second, does the responsiveness to price vary across households? Third, does government assistance in the form of lump-sum transfers offset the effect of price increases on demand? These questions have important implications for consumer welfare as well as for utility revenue purposes.

We argue that the tariff hikes were salient to consumers for at least eight reasons. First, people own and run their own heating system and are responsible for their own consumption. Second, the sheer magnitude of the tariff hikes, and the subsequent escalation of government energy assistance programs, suggest that the tariff reforms did not possibly go unnoticed. Third, each family receives the gas bill every month, with clear information about consumption for that month and the tariff(s). Fourth, Ukraine relies on one-part tariffs, which make the relationship between usage and the bill very clear. Fifth, the gas bill is not combined with other utilities (e.g., electricity or water). Sixth, the published rates are inclusive of taxes. Seventh, many households at our study locale maintain their own "utility book" where they manually record the same

[7] Some 30-40% of the households in Ukraine are served by district heating (Nithin Umapathi, World Bank, personal communication, 8 March 2019; Emerson and Shimkin, 2015).

[8] Sahari (2019) shows that the choice of heating system and fuel in single-family homes in Finland is influenced by the price of electricity.

information that appears on the bill. Last but not least, direct debit payment is uncommon: Most people bring their bills to the post office or to the bank to pay them, suggesting that the effect documented in Sexton (2015) is absent here.

In our study area gas meters are usually placed *inside* a dwelling. This means that attentiveness (Sallee, 2014) and usage monitoring are possible with a relatively low effort on the part of the consumer.

We assembled a panel dataset documenting monthly consumption from January 2013 to April 2017 for a sample of households in the Uzhhorod metropolitan area, and use it to examine the price elasticity. We wish to isolate changes in consumption due to behaviors, holding the structural characteristics of the dwelling and gas-using capital stock fixed, and, based on this notion, in our empirical work we restrict attention to those households that did not do any energy efficiency upgrades to their homes during our study period. (In other words, these households did not install insulation, or changed windows, put in a new boiler, switched to a different heating fuel, etc. between January 2013 and April 2017.) To identify cleanly the short-run elasticity, we further limit the analyses to a few months before and after the tariff changes.[9]

Unlike in Auffhammer and Rubin (2018), in Ukraine tariffs are not adjusted monthly to reflect the higher or low cost of acquiring natural gas for the utility: They are simply set exogenously by the regulator for a period of about one year at a time.[10] Because for part of our study period there was an increasing block tariff scheme, we are concerned with endogeneity of prices and quantity consumed at the consumer level, which we address with instrumental

[9] Deryugina et al. (2019) contrast a few months after municipal-level referenda about suppliers of electricity with two-three years after that event, and conclude that long-run price elasticity of electricity demand is -0.3, stronger than in the short run.

[10] Gas prices were regulated by the National Commission for State Regulation of Energy (NERC) from October 23, 2011 to October 1, 2015. The Ukrainian Cabinet of Ministers has been regulating the price of gas as an “energy carrier” ever since, while NERC retains the authority to set prices for gas distribution and transportation.

variable estimation. During our study period a number of households received “subsidies,” namely lump-sum government assistance to help pay the gas bills. We wish to see whether the subsidies offset the incentive to reduce consumption.

We find that the demand is not completely inelastic: Even without structural modifications to their homes, consumers were able to reduce usage meaningfully as tariffs were raised. When price doubles, consumption is cut, all else the same, by 7-22%. The reduction is however disproportionately small compared with the extent of the price hike, and implies a short-run price elasticity of -0.16, which falls in the low end of the range from earlier studies. Wealthier households and people living in multifamily buildings have less elastic demand functions. People seem to respond to current prices and not to future prices. We find modest evidence that households likely to hold different levels of “salience” have different price elasticities, but this effect may partly overlap with that of income and/or baseline consumption.

Taken together, these findings suggest that in this and similar settings (cold winters, no viable alternative to gas heat, a compliant population, price salience, relatively low effort required to monitor consumption), increases in natural gas prices would have limited effects on residential consumption and CO_2 emissions, raising the question whether measures aimed at improving efficiency might be more (cost-) effective. The offsetting effect of the subsidies is very modest. If both prices and subsidies were to double, consumption would still be reduced by about 10%, and consumption would still be reduced even if the proportional increase in the subsidies was greater, as long as it does not exceed a five-fold hike.

Researchers and policymakers have been struggling for decades with understanding incentives to conservation and the so-called energy efficiency gap, namely the sluggish pace at which energy efficient technologies are adopted by households (Jaffe and Stavins, 1994; Allcott and Greenstone, 2012). Some of our results hint at the possibility that those who do not adopt such technologies are likely the ones who—by necessity or skills—are the most capable of reducing consumptions through behaviors.

The remainder of the paper is organized as follows. We present background information in section 2. Section 3 presents the data, and section 4 lays out the model and estimation techniques. Section 5 presents the results and section 6 concludes.

2. Background

In May-June 2016, and then again in May-July 2017, we collected data about natural gas and electricity use by households in Uzhhorod, a city with some 113,000 residents in western Ukraine.[11] Unlike other parts of Ukraine, where district heating still serves a large share of the homes, Transcarpathia, the administrative region where Uzhhorod is located, started disconnecting dwellings from district heating in 2005 as part of a pilot project. The process was completed by 2012, which means that by the beginning of our study period (January 2013), everyone had installed and had been using their own separate heating systems, even in multifamily buildings. The majority of the homes in the Uzhhorod metropolitan area are heated by gas boilers (and radiators), and natural gas is supplied by PJSC Zakarpatgaz, a state-owned utility.[12]

People receive their gas bills every month, and charges are based on actual (not estimated or presumptive) consumption for that month, as per the monthly meter reading conducted by a

[11] Ukraine is a former Soviet republic with per capita GDP of $8,800 (2017 PPP dollars) in 2017, only 17% that of Germany and 15% that of the United States (CIA Factbook, see https://www.cia.gov/library/publications/the-world-factbook/, last accessed 21 March 2019). Internal political turmoil and conflict with Russia affected the country in 2014, and resulted in a negative growth in 2015 (real GDP growth -9.8%), followed by 2.5% growth in 2016 and 2017.

[12] Starting in 2015, PJSC Zakarpatgaz was made responsible for the distribution of natural gas, while the provision of gas itself was assigned to Zakarpatgaz zbut Ltd.

representative of the utility. The bills (see Figure 1) display clearly the meter reading at the end of the current and previous billing periods, consumption as the difference between them, the tariffs, and any applicable "benefits" or "subsidies" (described below). There is no fixed monthly charge: In other words, Transcarpathians pay a one-part tariff. Many households also maintain their own "utility book," where they manually record the same information that appears on the bill. It certainly helps that gas meters are most often *inside* the homes.[13]

The tariffs are set exogenously by the regulator and generally remain unchanged for about a year: Unlike in the US, they do not adjust monthly to mirror the higher or lower cost at which the utility has acquired natural gas (Auffhammer and Rubin, 2018). As shown in table 1 and figures 2-3, over the course of three years (from 2013 to 2016) gas prices to residential customers increased dramatically—by over 700% in nominal terms—in part because of the deteriorating relationship, and eventual conflict, with Russia, which cancelled deliveries to Ukraine, and in part to help the gas utility, which had until then been selling natural gas for industrial and residential use at highly subsidized rates, recover costs.[14]

Until March 2015 consumers faced a fairly complicated increasing block rate tariff scheme based on annual consumption with a mid-year assessment.[15] This scheme was replaced

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[13] Gas meters are located inside each unit of a multi-family building, and inside single-family and semi-detached homes built before 2004. Gas meters were placed outside single-family and semi-detached homes built in 2004 and later.

[14] Prior to the 2015 tariff reforms, Ukraine had the lowest household gas prices in the industrialized world and its economy an extremely high energy-intensity, comparable to that of Russia, but "without the latter's natural resource endowment" (Emerson and Shimkin, 2015, p. 3).

[15] To illustrate, initially there were a total of four blocks—from zero to 2500 m^3/year, from 2500 to 6000 m^3/year, from 6000 to 12000 m^3/year, and more than 12000 m^3/year. Suppose that a household in one year used 2000 m^3. At the beginning of the next year, the household would be charged the first-block rate for each m^3 consumed in each month. At the end of June, the utility would re-evaluate this household. If the household had used less than 60% of the block cutoff (namely, $0.60 \times 2500 = 1500$ m^3), it would continue to be charged the first-block rates. If it had exceed that cutoff (having consumed, for example, 1850 m^3), it would be bumped up to the second-block rate. At the end of the year, if the consumer had managed to stay below 2500 m^3, it would be assigned the first-block rate starting the next January, while if it had consumed between 2500 and 6000 m^3 over the year, it would be assigned the second block rate. This scheme was slightly simplified, and rates raised somewhat, in May 2014, when the regulator did away with the upper block, as can be seen in table 1 and figure 3.

in April 2015 by a two-block system during the heating season, with the block cutoff set at 200 m^3 per month, and uniform pricing the rest of the year, and dramatically higher rates per m^3 (see Figure 2). A consumer who used exactly 200 m^3 would have paid (1.089×200)=217.80 UAH in March 2015, but (200×3.6)=720 UAH in April 2015. A consumer using 400 m^3 would have paid (200×1.089+200×1.788)=575.40 UAH in March 2015, but (200×3.6+200×7.188)=2,517.60 UAH in April 2015. In April 2016, the block system was dropped and a uniform pricing scheme introduced. The rate was set at 6.879 UAH/m^3, seven times as much as what our 200-m^3/month customer would have paid only 13 months earlier. Electricity tariffs likewise rose during the same four-year period, but at a much lower rate (no more than 50% from one tariff regime to the next) and more frequently (Alberini et al., 2019).

What we have described above are the rates for regular residential customers. In practice, in Ukraine persons in certain professions (e.g., civil servants, the military, retirees, veterans, Chernobyl decontamination workers) receive so-called "benefits," namely discounted tariffs for the portion of their consumption that falls below a specified "allowance." The allowance is calculated by the government following a precise formula that takes into account family size, dwelling size, the number of stories of the building, whether gas is used for heating, cooking and/or hot water, and is seasonally adjusted. The allowances thus create additional tiers and the discounts with respect to the regular tariffs bring additional variation in rates (see Figure 4).[16]

The sharp increases in natural gas rates for residential customers in April 2015 and a year later triggered massive increases in prices and were a major cause of distress among the population. Government assistance however was, and still is, available, as families that struggle

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[16] Eligible households are enrolled automatically for benefits on the basis of professional status, services rendered to the government, date of birth, or family status. There is no issue of self-selection into the benefits program. Within the allowance, the tariff is reduced by 20% to 75%, depending on professional or personal status.

to pay their utility bills may be entitled to “subsidies.” The subsidies vary across eligible households and are lump-sum transfers meant to help cover the utilities. The gas subsidies thus do not change the marginal price of gas. Households do not actually receive cash: The subsidy amount is simply subtracted from the utility bill, thus reducing the balance due. The subsidy amount is clearly indicated on the bill.

The subsidy (usually referred to as Housing and Utility Subsidy, or HUS) is calculated following a non-linear formula that depends on (i) a means-tested eligibility threshold, (ii) the maximum amount of energy covered by the subsidy (i.e., normative consumption), and (iii) adjustment coefficients that vary across regions and seasons.[17] Since the subsidies are based on normative (not actual) consumption, which depends on size of the home, household size and heating fuel, households cannot influence the provision of subsidies through strategically increasing consumption, and thus have no incentive to do so. Subsidies do depend on income, but the authorities require exhaustive documentation of all sources of income, including recently liquidated assets.

During our study period, the share of the population that received subsidies in Ukraine increased from 9.9% to 46.5%, with a sharp increase in September-October 2016. The figures for Transcarpathia mirrored the national ones. Despite the financial pressure created by the new

[17] HUS beneficiaries are those households whose total housing and utility normative bill is above a threshold defined as (Y/SUBS)×br×k, where Y is total household income per household member, SUBS is subsistence level per household member (set by the government) as of the date when the subsidy is granted, br (=0.5) is base income ratio for the subsidy, and k (=.15) is the base rate for housing and utilities services. For instance, for a household with income that is just the same as the subsistence level, the threshold is 7.5%, which gets multiplied by total household income. Normative consumption is household-specific, and depends on the size of the home, on household size and on the type of equipment and heating fuel. For example, for a home that uses gas heat for the period after September 2014, the normative gas consumption was set as 23.6×hhsize + 11×min(21×hhsize, home area in m^2). The HUS payment is calculated as the difference between the total cost of normative consumption (i.e. the normative consumption for each type of utility, times the relevant tariff) and the maximum expenditure on normative consumption given household income ((Y/SUBS)×br×k)×income). If the latter exceeds the former, as might be the case for a relatively high-income household, the household is not eligible for HUS support.

tariffs and the subsidy eligibility changes during out study period, observers generally point out that families kept up their payment compliance (Laderchi and Umapathi 2017).

We ask three broad questions. First, residential gas demand is generally held to be relatively inelastic. But faced with such massive tariff hikes, are people capable of reducing consumption? Second, does the responsiveness to price vary across households? Third, if assistance in the form of lump-sum transfers increases consumption, how strong is this effect? These questions have important implications for consumer welfare as well as for utility revenue purposes.

3. The Data

A. Data Collection

We use a panel dataset that documents monthly natural gas consumption in a sample of Uzhhorod homes from January 2013 to April 2017. We collected this information directly from households in the course of interviews conducted in person by trained local enumerators. The enumerators were instructed to ask each respondent to produce as many electricity and natural gas bills as possible, going back to January 2013, and to transcribe the exact consumption during each billing period, the tariffs as shown on the bill, and any "benefits" or subsidies information.

The enumerator also recorded information about the type and size of the dwelling, energy efficiency (EE) renovations[18] that were done since January 2013, the home heating system type and fuel, major electric appliances, and the mode of payment of the utility bills. Each respondent (a person in the household who was familiar with the utility bills) was also asked about expected

[18] The renovations we inquired about are cavity wall insulation, attic insulation, double-glazed or triple-glazed windows, replacing the boiler, insulating the basement, and placing jackets around hot water pipes. These are simple technologies that are much needed in the housing stock of Ukraine, where 45% of the population lives in multi-family buildings, 70% of which date back to the Soviet period (Emerson and Shimkin, 2015).

natural gas tariff changes, any switch to a different heating system or newer equipment motivated by the tariff changes, ways in which the household tried to reduce their natural gas bills, and whether such efforts were successful. The questionnaire ended with sociodemographic questions.

The questionnaire was administered to the occupants of 500 residences selected to be representative of the housing stock in Uzhhorod in May-June 2016 (wave 1), and then again to 500 more households in May-July 2017 (wave 2). In wave 2, 250 interviews were conducted at homes selected to be representative of the housing stock,[19] and the remaining 250 were conducted at homes that we knew had at some point been thermally insulated, because such renovations were visible from the outside. The outside walls of individual units in multifamily buildings where insulation was recently installed, for example, tend to be of different color and appear to be thicker than the adjacent ones. We instructed the enumerators to scout for dwellings exhibiting such signs in the same neighborhoods as the remainder of the sample. Table 2 summarizes the sampling frame.

[19] We instructed our survey firm to collect 500 completed questionnaires in wave 1 and 250 in wave 2 using the following sampling frame. The samples were to be representative of the housing stock in the city of Uzhhorod and to include only homeowners, who are presumably responsible for energy consumption and bills, and in charge of any decisions about home energy efficiency upgrades, appliance purchases, etc. The homeownership rate in Ukraine is 93.7% (United Nations Economic Commission for Europe, 2013). The city of Uzhhorod is divided into nine districts and has a total population of 93,354 persons aged 18 and older (the total population is 113,000). For example, in wave 1 we wished to draw a sample of approximately half of one percent (=500/93,354) from the resident population in each district. The most populous district, New Town, has a total of 38,142 eligible residents, and half of one percent of them yields some 200 households. Four more districts resulted in a planned sample of 50 each, and the remaining four had 25 each. These figures were halved in wave 2. The samples were to mirror the distribution of housing types in Uzhhorod—57% apartments in multi-family buildings, 40% single-family homes, and some 3% row homes. A list of candidate addresses was drawn from each district using the Uzhhorod's resident registry, which documents the head of the household and the number of family members that live in each dwelling. The registry does not specify whether the family on the premises owns or rents the premises, and so the enumerators elicited that information at the very beginning, and terminated the interview if a prospective respondent was a renter. To encourage participation in the survey, we offered prospective respondents a card that entitled them to $3 worth of phone calls from their cellular phones. About half of the participants declined this offer and still completed the interview.

The questionnaire was administered only to households who owned their dwelling (the majority of the population of Transcarpathia and Ukraine as a whole). The two waves of surveys resulted in a response rate (out of valid contacts) of about 79% (see table 3).

B. The Data

We merged the monthly natural gas consumption, "benefits" and subsidy data with weather records and tariffs, and created a panel dataset where the cross-sectional unit of observation is the family/dwelling. The panel is unbalanced, since not everyone was able to find all of his or her monthly gas bills going back to January 2013, and the maximum longitudinal size is T=40 for wave 1 and T=52 for wave 2.

Table 4, panel A, summarizes the structural characteristics of the dwelling by wave of the survey. The two waves are similar in terms of dwelling type, size, vintage, and prevalence of natural gas as the primary heating fuel (72%). Wave 2 has a somewhat higher household income in nominal terms, but this is likely due in part to changes in the national wage rates that occurred between the two waves of the survey.[20]

Table 4, panel B, examines the EE renovations concerning space heating since January 2013. The most popular are window replacement and wall or attic insulation. The prevalence of these EE measures is higher in wave 2, as is to be expected due to the nature of the sampling and the fact that more time had elapsed since January 2013. Virtually everyone used their own savings to finance these upgrades.[21] We also asked respondents whether they had switched from

[20] Statistics Ukraine reports that between 2016 and 2017 the average nominal salary in Transcarpathia increased by about 47% (www.uz.ukrstat.gov/ua/statinfo/vitrat/2018/struct resurs 1999-2017.pdf).

[21] In wave 1, 174 families out of 181 who had done EE upgrades financed them exclusively with their own money. The remaining 7 used a combination of own and government-program funding. In wave 2, 351 of the 386 households who had done EE renovations financed them entirely on their own; 33 financed them in part from government programs, including government loans and "Warm Loans," and the remaining 2 availed themselves

one heating fuel to another since January 2013, and found that only one respondents had switched to solid fuels, and no one had gone from using natural gas to using electric heat, or viceversa. This is in sharp contrast with Krauss (2016), who finds that between 2009 and 2011 some 8% of the households in Armenia shifted away from natural gas after the gas tariffs were increased by 40%.

Finally, table 4, panel C, presents summary information about gas usage and about the share of the respondents in each wave of surveys who receive benefits. Benefits recipients account for 7% and 5% of the sample in wave 1 and 2, respectively. For these persons, the allowance can be quite substantial and the discount off the regular tariffs (for the cubic meters within the allowance) averages 35% and 46%, respectively. No one reported subsidies in wave 1, whereas 27.8% of the households in wave received subsidies.[22]

In sum, overall the two waves appear reasonably similar in terms of dwelling characteristics and type of heating equipment. In the remainder of this paper, we focus on the subset of households/dwellings from combined waves 1 and 2 where no EE upgrades were done since January 2013. There were a total of 572 such dwellings. Our first order of business is thus to compare these dwellings/families (henceforth dubbed the "non-renovators") with the 428 from combined waves 1 and 2 that did do renovations since January 2013 (the "renovators").[23]

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exclusively of "Warm loans." "Warm loans" are a government-approved program in partnership with private banks. This program has been criticized because of the high interest rates (up to 27% per annum) on these loans.

[22] The subsidies as listed on the bills were cross-checked with an on-line searchable database set up by the Ukrainian government ("Ioc Minsocpolityky Ukrainy," Information on the status of the subsidy in the household according to the data of the Unified State Register of Subsidy Recipients of the Ministry of Social Policy of Ukraine, https://subsidii.ioc.gov.ua/, last accessed 18 November 2018).

[23] We wish to emphasize that in this paper we define as non-renovators simply those households that had done no energy efficiency renovations from January 2013 to the time of the survey. A number of people that did not do any upgrades after January 2013 had done energy efficiency upgrades including insulation, new windows, new heating equipment, etc. *before* January 2013. Of the 345 non-renovators from wave 1, 256 had done one or more of these upgrades 4-10 prior to the time of the survey. Out of the 227 non-renovators from wave 2, 139 had done upgrades in the 5-10 years before the time of the wave 2 survey.

Table 5 shows that non-renovators and renovators are similar in terms of size of the home, prevalence of multifamily or single-family homes, and natural gas as their main heating fuel. Homes with electric heat are however more heavily represented among the renovators. The two groups do not differ significantly in terms of benefits, but the non-renovators are less likely to receive subsidies.

The second panel of table 5 shows that the non-renovators use less natural gas in the winter but a little more in the summer, and are faced with lower marginal prices. The difference in marginal gas prices paid is statistically significant at the conventional levels (t stat=-13.58).

Out of the 572 households that did not do any energy efficiency upgrades since January 2013, 514 use natural gas for space heating, cooking or water heating purposes. A total of 305 come from wave 1, and 209 from wave 2. Their gas usage follows a seasonal pattern, as is apparent in Figure 5, which also shows that (log) gas consumption appears to decline over time.

Summary statistics for the weather are displayed in table 6. The annual heating degree days (base: 65° F) are typically 5400-5700, making Uzhhorod roughly comparable to Chicago.

Our questionnaire asked respondents how they pay their gas bills. Most of them pay in person at the post office (34.35%) or at their bank (49.02%), 15.97% pay online, and only 0.66% uses automatic debit. This suggests that it is extremely unlikely that tariff changes will go unnoticed as in Sexton (2015). The gas meter is inside the home for 93% of the dwellings in our sample.

4. The Model

Attention in this paper is restricted to the 514 households from both waves that use natural gas and did not do any EE renovations between January 2013 and April 2017. The stock of gas-using capital is therefore held constant, and any reductions in use, all else the same, are attributed to behaviors.

We estimate the regression equation

(1) $$lnG_{it} = \alpha_i + \tau_t + \mathbf{W}_{it}\boldsymbol{\beta} + \gamma_1 \cdot \ln P_{it} + \gamma_2 \cdot \ln S_{it} + \gamma_3 \cdot D_{it} + \varepsilon_{it}$$

where *i* denotes the household, *t* the month and year, *G* is monthly natural gas consumption, P is the marginal price faced by the household,[24] *S* is the subsidy amount and *D* is a dummy denoting that the household receives subsidies but the exact amounts are not available, interacted with a heating season (October through April) indicator.[25] Because we have a monthly panel and the sample is restricted to those that did not adjust their gas-using capital stock during our study period, we interpret coefficient γ_1 as the short-run or behavior-only price elasticity of demand.

Vector $\mathbf{W}_{it}$ includes weather variables, plus i) vintage of the building interacted with a dummy denoting the heating season, ii) income above the sample median-by-month effects, and iii) single-family (SF) home-by-month effects. The purpose of these covariates is to account as much as possible for the different extent of seasonal fluctuations in consumption across households. Since we have household income at the time of the survey, but not month by month over our sample period, item ii) above and the subsidies, *S*, are our best way to account for the budget available for gas expenditure in any given month.

Equation (1) includes household-specific effects and time fixed effects. The former account for unobserved heterogeneity among households, capture the effect of any pre-existing insulation measures, and are the appropriate way to handle our sampling frame (which entails some choice-

[24] Ito (2014) has conjectured, and found empirical evidence in support of, the notion that in the presence of block pricing residential consumption responds to the average price, rather than the marginal price. Ito (2014) shows that when this is the case, households consume more than that if they had responded to marginal price, thus defeating the purpose of increasing block pricing, which is to encourage conservation. Based the histograms in Figures 7a and 7b, we believe that it is reasonable to assume that people were responding to the marginal price.

[25] S is coded to zero for those respondents who received subsidies, but the exact amount is unknown.

based sampling), since the analysis is conditional on the fixed effects. The latter control for economy-wide events that could have affected consumption (e.g., the state of the economy; the exchange rate with the dollar or the euro; conflict with Russia) or seasonal effects that might explain natural gas consumption in any given month (e.g., the number of days in that month; holidays or other events where people spend more/less time at home, thus demanding more/less heat, etc.). Our time fixed effects are month dummies plus "tariff regime" dummies.[26]

Estimation of equation (1) is complicated by the fact that, in the presence of (increasing) block pricing the marginal price is endogenous (and positively correlated) with consumption, as the consumer chooses jointly the desired level of consumption and the price that accompanies it. Unless properly addressed, the positive correlation may result in the appearance of a positively sloped demand function. To circumvent this problem, we instrument for log price. Our excluded instruments are the log tariffs in each block (Nieswiadomy and Molina, 1989; Mansur and Olmstead, 2012), plus the log allowance and log discount off the regular tariff if the household receives benefits.[27] The latter two are exogenous, alter the rates and hence the marginal price faced by that household, and should not directly influence consumption.

We estimate the model in the first differences:

(2) $$\Delta lnG_{it} = \tau_t^* + \Delta \mathbf{W}_{it}\boldsymbol{\beta} + \gamma_1 \cdot \Delta \ln P_{it} + \gamma_2 \cdot \Delta \ln S_{it} + \gamma_3 \cdot \Delta\, D_{it} + e_{it}.$$

The first stage is

(3) $$\Delta lnP_{it} = \theta_t + \Delta \mathbf{W}_{it}\boldsymbol{\lambda}_1 + \lambda_2 \cdot \Delta \ln S_{it} + \lambda_3 \cdot \Delta D_{it} + \Delta \ln \boldsymbol{TARIFF}_{it}\boldsymbol{\delta} +$$

$$+\Delta \boldsymbol{BENEFITS}_{it}\boldsymbol{\pi} + u_{it},$$

[26] Our tariff regimes (or tariff periods) are January 2013-April 2014, May 2014-March 2015, April 2015-April 2016, May 2016 to March 2017, and from April 2017.
[27] The log gas allowance and log discount off the regular tariff are coded to zero for those households who do not receive benefits.

where lnTARIFF is a vector of five variables containing the log rates per m^3 in block 1 through 3 until March 2015 and in blocks 1 and 2 from April 2015 respectively, and BENEFITS includes the log gas allowance and the log discount off the regular tariff when consumption falls within the monthly allowance. The standard errors are clustered at the household level.

5. Results

A. Checking for Sample Selection Bias.

We first examine the availability of the gas usage data and make sure that there is no sample selection bias. In figure A.1 in the Appendix we plot the percentage of bills produced by the respondents in each month of the study, starting from the most recent bill (May 2016 for Wave 1 and May 2017 for wave 2) and going back in time. It is clear that the share of bills available declines the further back in time from the time of the survey: Presumably people tend to keep the most recent bills and discard the older ones. The rate at which they do so is roughly the same for both wave 1 and wave 2. Of the 514 people who use natural gas and did not do any EE upgrades to their homes during our study period, 116 produced 40 or more bills (22.56%), 34 (6.61%) 30 to 39 bills, 162 (31.52%) 20 to 29 bills, 200 (38.91%) 10 to 19, and only 2 (less than 1%) between 1 and 9.

To check for possible systematic attrition, we specify a regression where the dependent variable is log gas usage in year and month t. The regression includes respondent-specific fixed effects, month-by-year fixed effects, covariates $\mathbf{W}_{it}$, the benefits information, and a dummy denoting whether the bill (and hence information on gas usage) was available in the previous month. An insignificant coefficient on this dummy is interpreted to mean that the presence or absence of a bill is not systematically related to consumption levels, and that there is no evidence of systematic attrition (Wooldridge, 2010, p. 823-4). The coefficient on this variable (-0.0381; t stat. -1.76) is indeed insignificant at the 5% and 1% levels. Based on this, we proceed to our main analyses.[28]

B. Do Tariffs Really Matter?

Figure 5 shows that consumption has generally declined over time, but does not tell us for sure whether that is because of milder winters and summers, or as a result of the tariff changes. The winter of 2017 was actually colder than that of 2016, which in turn was colder than that of 2015, and yet consumption seems to be less.

Figure 6 is constructed after running a regression similar to that of equation (1), limited to the data before April 2015 and excluding prices, and using the coefficients from that regression, plus actual weather since April 2015, to predict what consumption would have been from April 2015. The figure shows clearly that based on pre-April 2015 consumption patterns, one would predict higher usage levels than the ones actually observed in and after April 2015. In other words, people appear to have cut consumption after the tariff reform of April 2015.

This still does not prove unambiguously that people were responding to the gas tariff changes rather than to something else. We do not have a control group in our sample: Everyone was subject to the tariff changes, but we take advantage of the different intensity with which people experienced them, depending on consumption levels and “benefits” status.

For additional evidence, Figures 7a and 7b are histograms of consumption between April 2015 and March 2016, and from April 2016. Figure 7a shows evidence of bunching around 200

[28] Among other things, the lack of attrition bias means that when a respondent reports usage for month 34 of the study but not 33, it is acceptable to construct the first difference as (ln Gas34 – ln Gas 32). This will be explained by the change in weather between months 34 and 32, and all of the other covariates in a similar fashion.

m^3 in the former period, when this was the block cutoff during the heating season. The histogram in figure 7b is much smoother around 200 m^3, displaying no evidence of bunching around that level, which is exactly what we would expect, since the block system had been by then eliminated. These histograms suggest to us that people were aware of the tariff reforms and responded to them.

C. Short-run Elasticity

We begin with estimating equation (2) by ordinary least squares, without instrumenting for the change in log marginal price. The results from this regression are reported in table 7. Unsurprisingly, due to the presence of an increasing block pricing scheme for at least part of the time, the coefficient on Δlog price is positive (but significant only at the 10% level). The subsidy elasticity is 0.02 and insignificant.

The short-run elasticities from IV estimation of equation (3) are displayed in tables 8-11 for different subsets of the data. In general, the first stage performed very well, producing R-squares of around 0.74. The log tariffs in each block and the log benefits were significant predictors of the log marginal price of natural gas. We follow Andrews et al. (2018) and use the effective F (Montiel Olea and Pflueger, 2013) as our diagnostic of the strength of the instruments.[29] The effective F statistics are large and all exceed 23.11, the rule-of-thumb 5% critical limit critical limit that is asymptotically valid for the 2SLS estimator, indicating that the bias of the 2SLS estimator is small compared to the worst-case bias.

[29] When the instruments are weak (i.e., they have low correlation with the endogenous regressor), the 2SLS estimates tend towards the OLS estimates, are just as heavily or even more heavily biased, and have a non-standard distribution. Staiger and Stock (1997) recommend using the F statistic of the null hypothesis that the coefficients on the excluded instruments in the first stage are equal to zero, and consider the instrument strong if the F is at least 10.

The coefficients on log subsidy and the subsidy dummy were insignificant at the conventional levels in the first stage, which confirms our reasoning that they—as a lump sum transfer—should have no effect on the marginal price.

The short-run or behavior-only price elasticity for the full sample is around -0.16 and significant at the 1% level. Households with income below the sample median tend to exhibit more pronounced price elasticity (-0.20), as do households who live in single-family homes (-0.22). By contrast, households living in units in multi-family buildings are less sensitive to price.[30]

The subsidies—an income transfer—have a negligible effect on consumption. The elasticity of demand with respect to the subsidy is positive, as expected, and around 0.02 but statistically insignificant. The dummy denoting that subsidies are received but their exact amount is unavailable, interacted with the heating season dummy, is likewise an insignificant determinant of consumption. The magnitude of the subsidy elasticity (0.02) indicates that it would take an 800% increase in the subsidy to offset completely the effect of a doubling in marginal price, like the ones from April to May 2015 or April to May 2016. Dropping the respondents who received subsidies from the sample has little effect on the price elasticity, which is equal to -0.1593 (t statistic -5.17).[31] The households living in single-family homes are the ones with the strongest responsiveness to both price and subsidies.

Table 9 reports results from separating our sample into two groups—namely those who had, or had not, done some EE improvements 1-7 years before the study period. The latter

[30] In four out of the five 2SLS regressions displayed in table 7 the Hansen J test fail to reject the null that the instruments are valid at the 1% level. (The software was unable to calculate the test in the remaining one case.) We also checked whether the *BENEFITS* variables are valid *excluded* instruments using the difference-in-Sargan test. For large samples and under the null, this statistic (also dubbed C statistic) is distributed as a chi square with three degrees of freedom (see Baum et al., 2003, and Wooldridge, 2010, p. 134-137). The test did not reject the null in the three 2SLS regressions for which it was possible to calculate this statistic.

[31] This is regression is not reported in table 8. It is based on 11163 observations from 455 households.

exhibit a stronger elasticity (-0.2330) than the former (-0.1458). Although these coefficients are not significantly different from one another (Wald statistic 1.6380, p value 0.75), the results do hint at the possibility that those with the least EE uptake might be those by—by necessity or skills—are more adept at attaining consumption reductions through behaviors. It is interesting that these subjects are twice as sensitive to subsidies.

D. Different Time Periods

Table 10 reports the price elasticities for specific periods of time. The responsiveness to price seems to be stable across the heating and non-heating seasons, and when we restrict the sample to a relatively narrow window around the time when the tariff changes take place.

Table 10 also presents the results of a regression where we limit the sample to after January 2014 (as the bills from 2013 are sparse) but before October 2016, when the number of recipients of subsidies soared in Transcarpathia and in the rest of the country. The results suggest that when people are fully responsible for paying their bill, they tend to be more responsive to price. The price elasticity is -0.21. The subsidy elasticity is still 0.02 and still statistically insignificant.

All in all, our results suggest that in the face of extreme tariff changes, households were able to reduce their natural gas consumption, even without installing (new) insulation or making any other energy efficiency investment. All else the same, a price change of the magnitude that was observed between March and April 2015 (230% for a 200 m^3 customer), would have resulted, all else the same, in a reduction in consumption by 18-37%, based on the range of estimates reported in tables 8-10.

A 100% increase in tariff or marginal price (e.g., April to May 2016) would have reduced consumption by 7.88% to 22%, if no changes in subsidies were experienced. If subsidies were doubled, the model predicts a 4-14% decline in consumption. If the price elasticity is -0.1643 (table 8, column (A)), the subsidies would have to be more than quintupled (a 460% increase) for consumption to remain unchanged.

F. Checks

Since natural gas prices are posted for the present and for future tariff periods on a dedicated web page of the National Commission for State Regulation of Energy and Public Utilities (NERC), one wonders whether the earlier results might be biased by possible anticipation of future price increases. To test for this, we enter future tariffs (specifically, the tariffs in block 1 through 3 for the next month, which are identical when the tier system is abolished) in the right-hand side of the regression, but, as shown in table 11, the coefficients on this future tariffs are statistically insignificant—both individually and jointly.

We have argued that the large rate increases experienced over our study period should be "salient" to people, because of their sheer magnitude and impacts on household budgets, which forced the government to escalate assistance measures, and for a number of other reasons. But were they really salient to the individual households in our sample? The most natural way to check would be to ask survey respondents to report the current and past rates, and compare their reports with the true rates (or ask them for a direct assessment of the salience of the rate changes). This proved impractical in the course of our survey, but we were able to elicit the respondents' own estimates of their average bills and consumption levels for winter and summer.

Since the surveys took place just after the end of the heating season, we expect the respondent to recall the bills and usage for the most recent heating season best. We calculated average bills and consumption for the most recent heating season (October 2015-April 2016 for wave 1 respondents, and October 2016-April 2017 for wave 2 respondents), and compared their own assessments with the true winter-time averages. Respondents can be classified into one of four groups: i) those who are fundamentally correct (their estimates bracket the true average), ii) those who overestimate the true average, iii) those who underestimate it, and iv) those who simply didn't know.

Out of the 509 households for whom we were able to calculate the average monthly consumption for the most recent heating season, 203 (39.88%) were in the ballpark, 265 (52.06%) overestimated consumption, 27 (5.30%) underestimated it, and 12 didn't know. As shown in table 12, those who correctly estimate their consumption are less sensitive to price, while the price elasticity is stronger among those who overstated their usage. This is consistent with interpreting an overstate usage level as a hint that the tariff changes were meaningful and salient to the respondent, but also with the possibility that the price elasticity is higher *because* the respondent was in fact trying to reduce usage.

Presumably salience is especially pronounced for light users, who in this context experienced a starker proportional increase. "Heavy users" (those with average monthly usage greater than 224 cubic meter a month, or the top 25% of the distribution) do exhibit have an elasticity that is some 27% stronger than that of "light users" (everyone else; -0.1995 v. -0.1573, respectively). However, a Wald test does not find these two elasticities to be significantly different from one another (Wald statistic 0.3628, p value 0.4530).

Finally, we wish to test whether easy access to the gas meter, which has the potential to counter inattention, makes a difference. When the sample includes only dwellings with indoor gas meters, the price elasticity is -0.1566, and it is further limited to single-family homes with indoor gas meters, the price elasticity is -0.1739.

6. Conclusions

We have taken advantage of the recent and abrupt natural gas tariff reforms in Ukraine to estimate the price elasticity of residential gas demand. Because we have monthly usage records from individual households, and attention is restricted to households who did not change their heating equipment, installed insulation or otherwise improved the thermal integrity of their home during our sample period, we interpret our estimates as behavior-only, short-term price elasticities. We also estimate models based on shorter windows around the times when the tariffs were changed.

We find that consumers *are* capable of reducing consumption when the price of gas increases, even without making structural modifications to their homes. The price elasticity is however low, as expected when opportunities for substitution are limited. We find that wealthier households have an even less elastic demand, along the lines of Krauss (2016) for households in Armenia, another former Soviet republic where people were faced with gas tariff reforms (albeit much more modest than in Ukraine) and demonstrated a willingness to substitute towards other heating fuels. Our results hint at the possibility that those with the least EE uptake might be those who—by necessity or through skills—are most capable of reducing usage through behaviors alone.

Earlier research has raised the issue of whether small tariff changes lack salience (Deryugina et al., 2019), which may explain apparent low price elasticities. We have selected a locale where the sheer magnitude of the tariff hikes and a variety of other factors (including the fact that households are responsible for their own heating expenses, the format of the bill, and a history of compliance and attention to utilities) “should” imply salience, and have for good measure also examined whether the elasticity is different for groups of people with different knowledge of their consumption levels (which may signal the strength of salience) or for whom the tariffs hikes had a different proportional impact (which presumably affects salience).

We have found some evidence consistent with the notion that the stronger the salience, the stronger the responsiveness to price, although this effect is modest and may partly overlap with that of income and/or baseline consumption levels. We have also checked whether people might be responding to announcements about future prices, but have found that once the current price is included in the model, future tariffs do not influence consumption.

Importantly, our models control for the subsidies, the lump-sum assistance provided by the government, and find a very small and insignificant subsidy elasticity of demand. Were we take this elasticity at face value, it would imply that when the marginal price of gas doubled, even households that received subsidies reduced consumption, as long as the subsidies did not increase by more than 460%. If both prices and subsidies doubled (as happened between April and May 2015, or April and May 2016, for prices), consumption is still predicted to decrease by about 4-14%. This is somewhat reassuring in view of the statements by government and utility officials that the subsidies had failed to deliver significant reductions in natural gas usage (primarily because they had not stimulated sufficient energy efficiency improvements).[32]

[32] See, for example, https://www.president.gov.ua/en/news/sistema-subsidij-maye-stvoryuvati-motivaciyu-dlya-ekonomiyi-42534, http://annualreport2016.naftogaz.com/en/jak-mi-pracjujemo/energoefektivnist,

Are these reductions in consumption credible for households that did not any structural EE renovations but did have gas meters inside the home? Earlier non-structural attempts to moderate the use of energy in homes have focused on the provision of information, in the form of in-home displays and smart meters ("direct feedback"), more informative bills ("indirect feedback"), sometimes combined with behavioral "nudges," and education through energy audits. These have been most often done for electricity, and have resulted in energy use reductions of 2-15% (European Energy Agency [EEA], 2013; Gans et al., 2013).

Efforts specific to residential gas usage have been less frequent, and have included similar information treatments, variable pricing (see Commission for Energy Regulation, 2011), and community initiatives based on voluntary commitments (see EEA, 2013). Overall, these interventions have produced reductions of 1-21% (EEA, 2013; Kerr and Tondro, 2012; Aydin et al., 2018). Based on this evidence, we conclude that in the presence of large price increases, relatively inelastic demand, high salience and compliance, and relatively low-effort usage monitoring, households are capable of reducing gas consumption through behaviors to an extent comparable (in percentage terms) to that seen in non-price, information-feedback, interventions.

https://voxukraine.org/en/9-facts-about-the-system-of-subsidies-in-ukraine-and-the-real-gas-prices-for-the-population (in English); https://www.kmu.gov.ua/ua/news/gennadij-zubko-zmenshiti-vitrati-domogospodarstv-mozhna-tilki-za-rahunok-znizhennya-energospozhivannya, https://expres.online/archive/digest/2017/03/18/233410-navishcho-ekonomyty-pidrahovano-vidriznyayetsya-spozhyvannya-gazu-budynkah, https://dt.ua/ECONOMICS/diyucha-sistema-subsidiy-niyak-ne-motivuye-naselennya-ekonomiti-na-spozhivanni-gazu-213192.html; http://uacrisis.org/ua/43443-mehanizm-subsidij (in Ukrainian) (last accessed on March 20th, 2019).

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Figure 1. Sample Gas Bill.

Постачальник: ПАТ "Закарпатгаз" ВОРФО м. Ужгород, вул. Погорелова, 2 тел.(0312) 61-21-46, 66-39-98, **р/р 26037301083700 МФО 312356** **Код 05448610**

Рахунок сплатити протягом 10 днів. Виправленню не підлягає.

РАХУНОК №821489/11

на оплату за спожитий природний газ за **Листопад** 2014р.

[redacted] **Споживач**: [redacted] **Адреса**: Ужгород, вул. Можайського, буд. 34, кв. 19.

Пільги- Осо 50%- 2 . **Лічильник** G4, №8046180.

Показники лічильника			Ціна, 1м3: 1,089 грн.		
Попередній	Фактичний на дату 30.11.2014	Плановий, на кінець місяця рекомендов.	під час відсутності лічильника, м3.	в т.ч. по пільзі, м3.	Всього нараховано, м3.
444	647	0			
203 м3	0 м3		0,00	191,09	203,00

Нараховано всього, грн.	Пільги, грн.	Рекомендована сума до сплати, грн.
221,07	104,05	117,02
Залишок на рахунку		75,67
Коригування		0,00
Субсидія		0,00
Оплачено:		75,67
Всього до сплати, грн.:		**117,02**

Увага! Сплачувати за газ можливо через платіжну систему на сайті http://ipay.ua Детальна інформація на сайті http://zk.104.ua

Figure 2. Electricity and Gas Tariffs (2013-2017). Tariffs paid by a 200 kWh/mo. electricity consumer and a 200 m^3/mo. natural gas consumer.

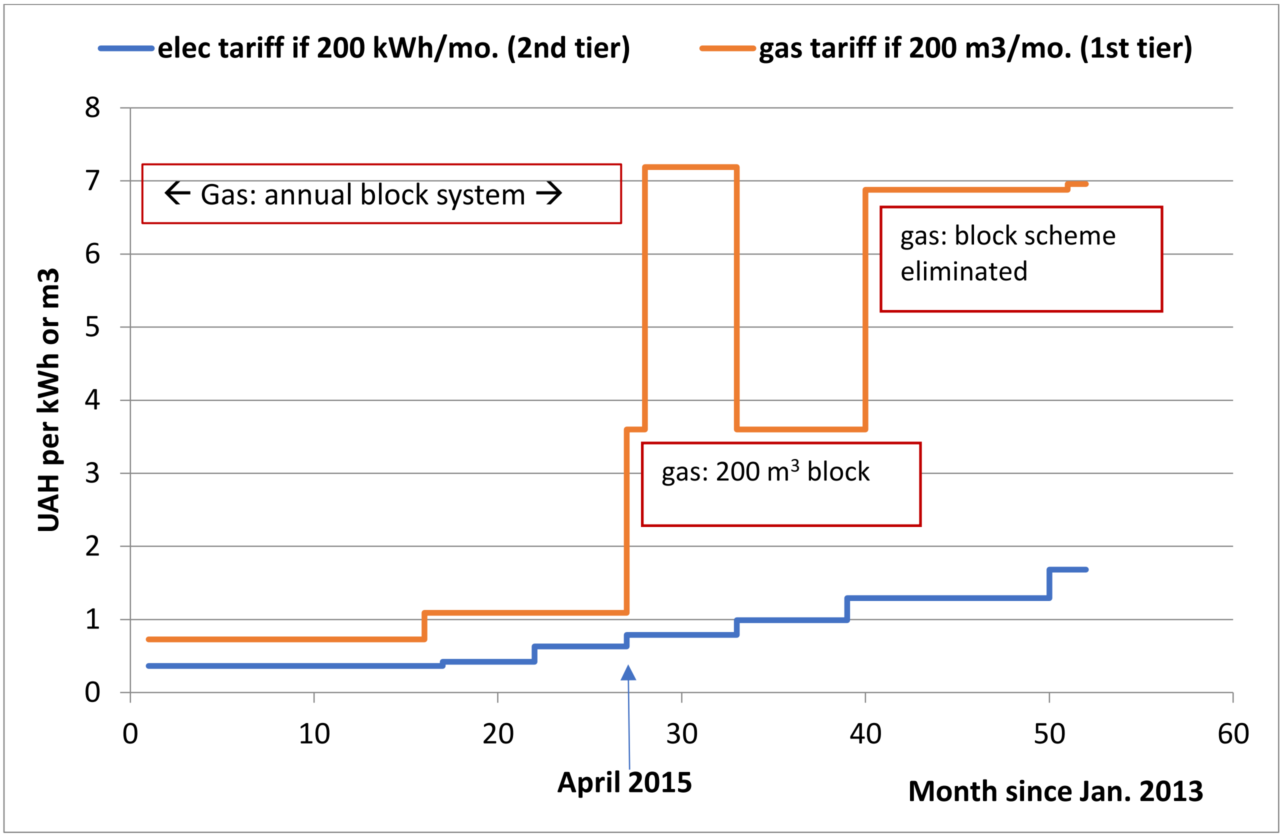


Figure 3. Gas Tariffs (2013-2017).

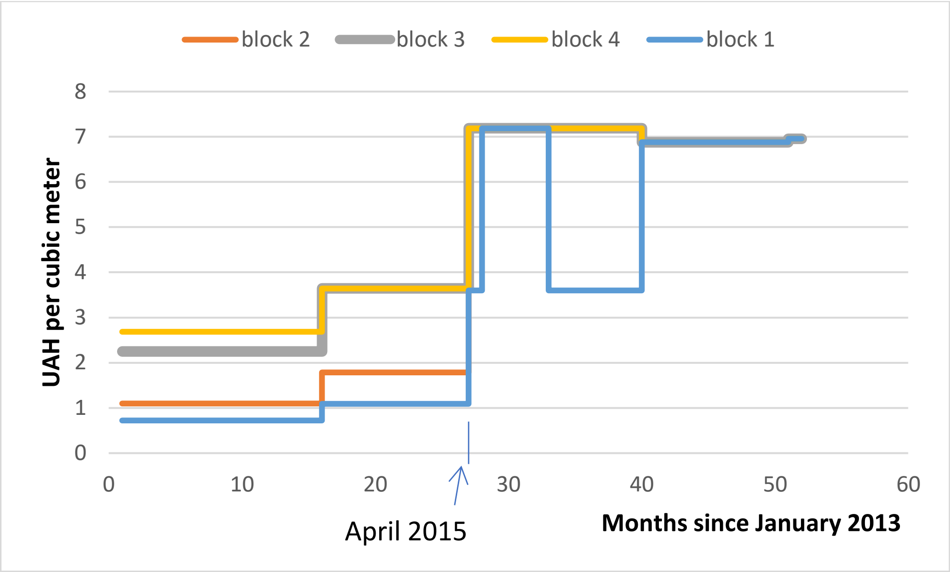


Figure 4. Benefits rates v. regular tariff with two-block tariffs (heating season: April 2015; October 2015-March 2016). The hypothetical household on benefits rate receives a 50% discount off the regular rate when consumption is within the allowance (here assumed to be 250 m^3/month).

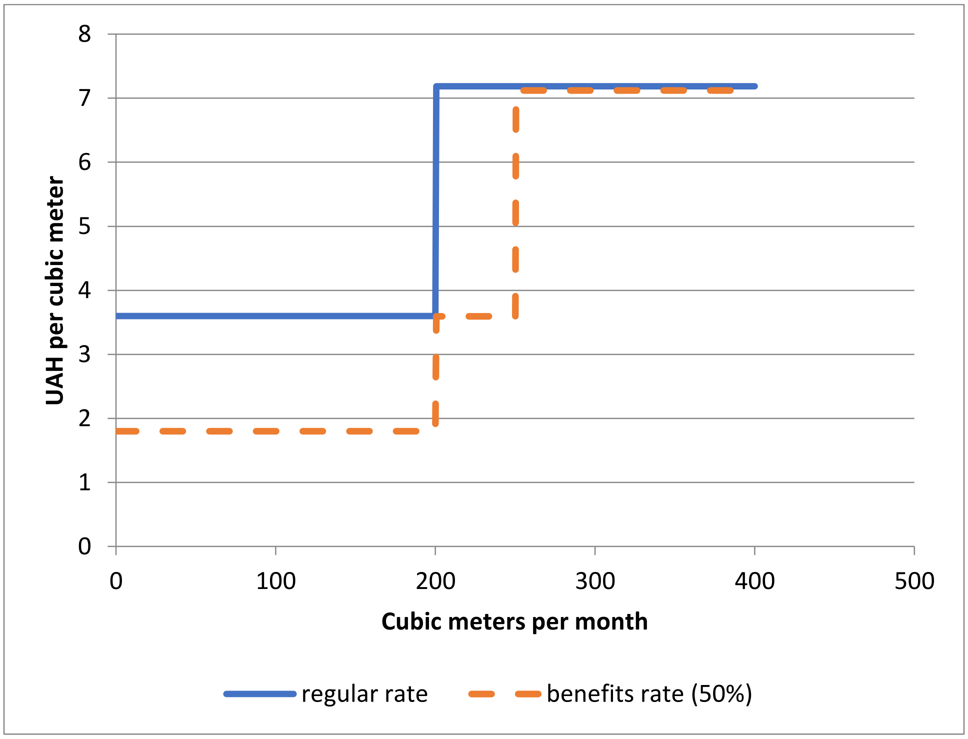


Figure 5. Average log monthly gas consumption by month for households that did no EE upgrades after January 2013.

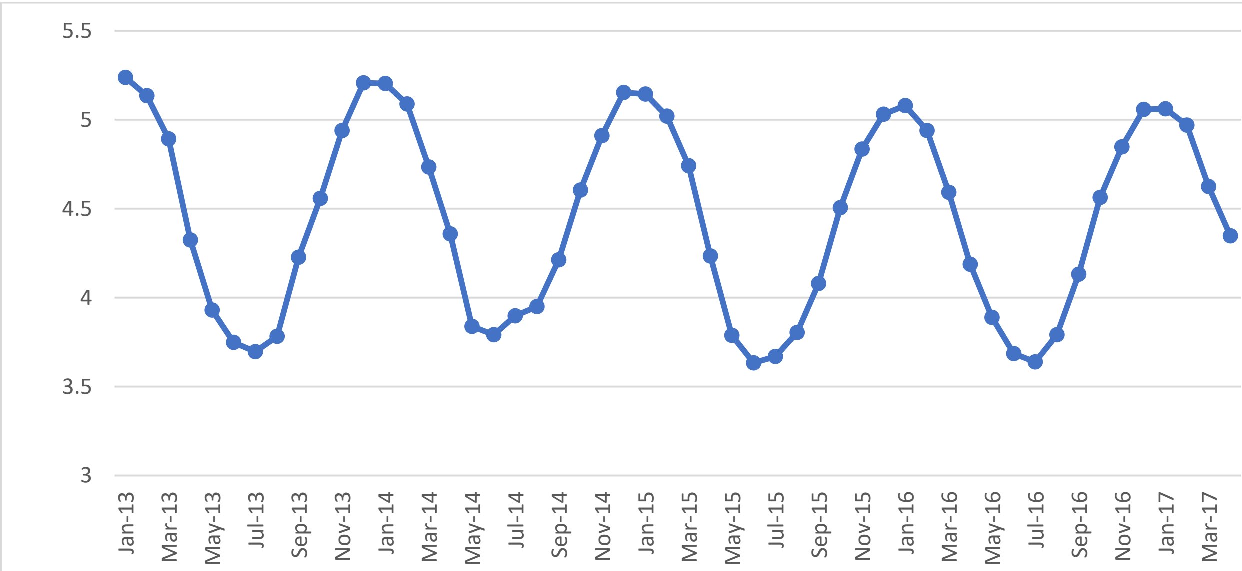
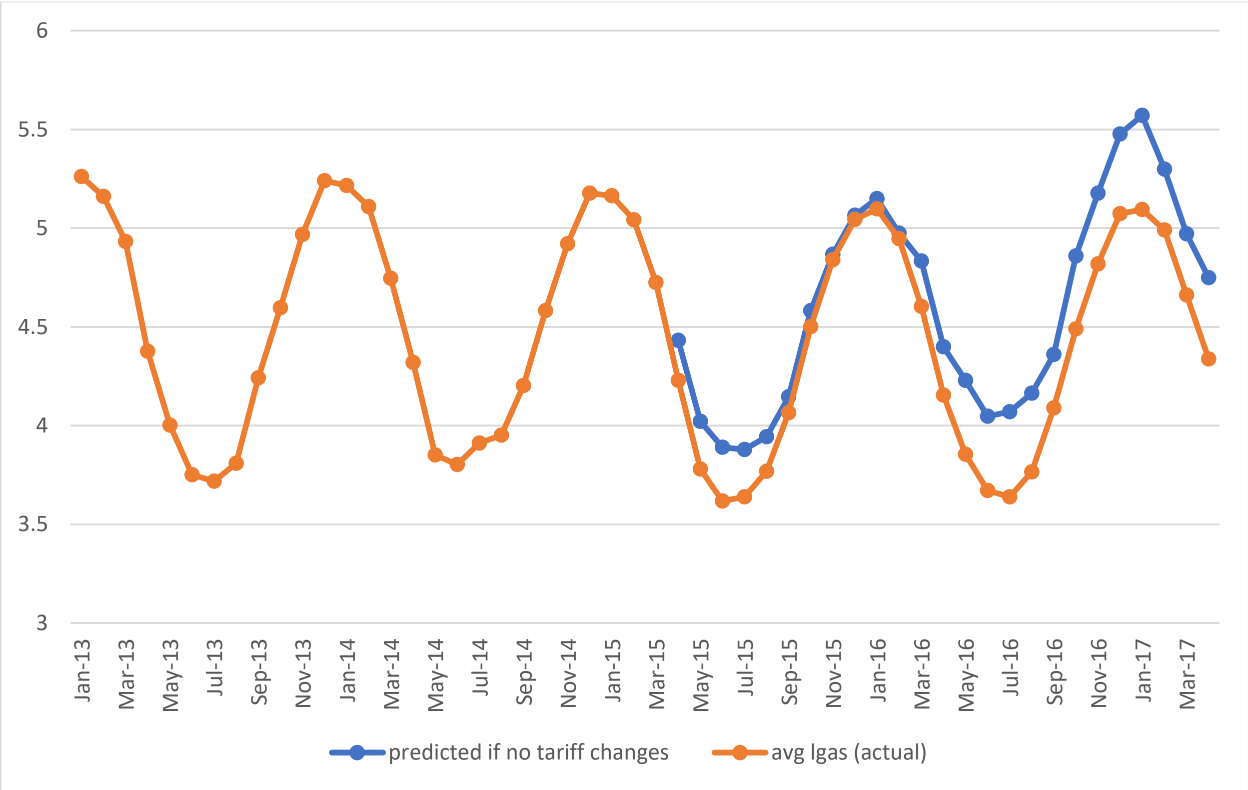


Figure 6. Average actual ln gas consumption (in orange) and average predicted ln gas consumption (in blue) if the patterns before April 2015 had continued.



Predictions for April 2015 and later months were formed by first regressing log gas consumption on household-specific fixed effect, tariff period fixed effects and weather, and then forming predictions for April 2015 and the subsequent months at the actual weather, using the coefficient on the dummy for the tariff period in force before April 2015.

Figure 7.a. Histogram of monthly consumption from April 2015 to April 2016. The vertical line is placed at 200 cubic meters per month, which was the block cutoff during the heating season.

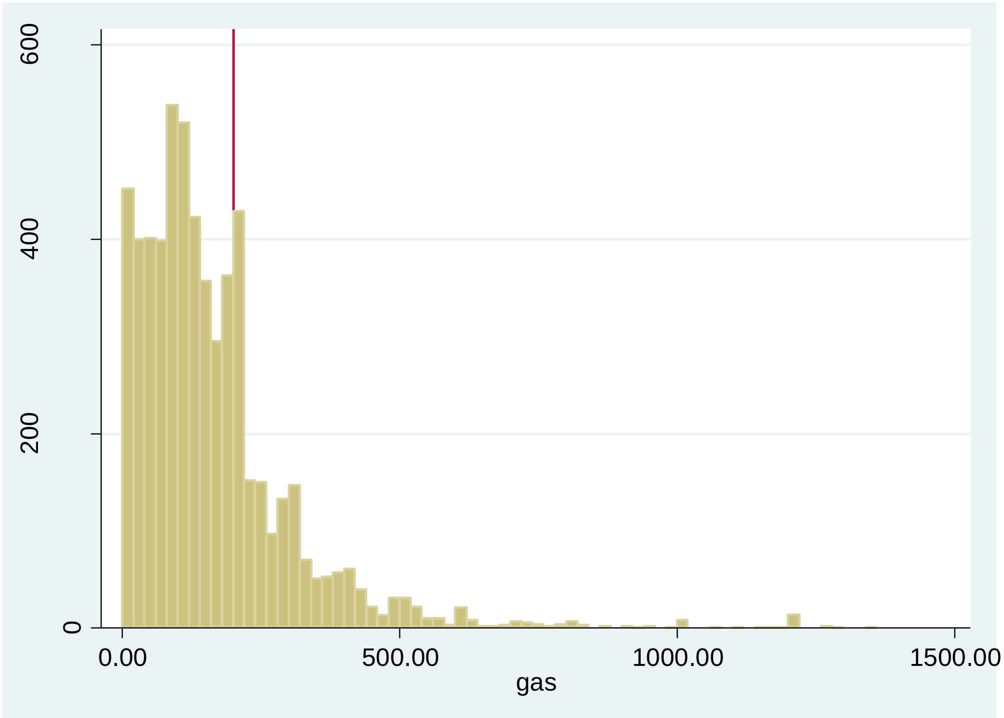


Figure 7.b. Histogram of monthly consumption from May 2016 to April 2017. The vertical line is placed at 200 cubic meters per month, which was by then the obsolete block cutoff.

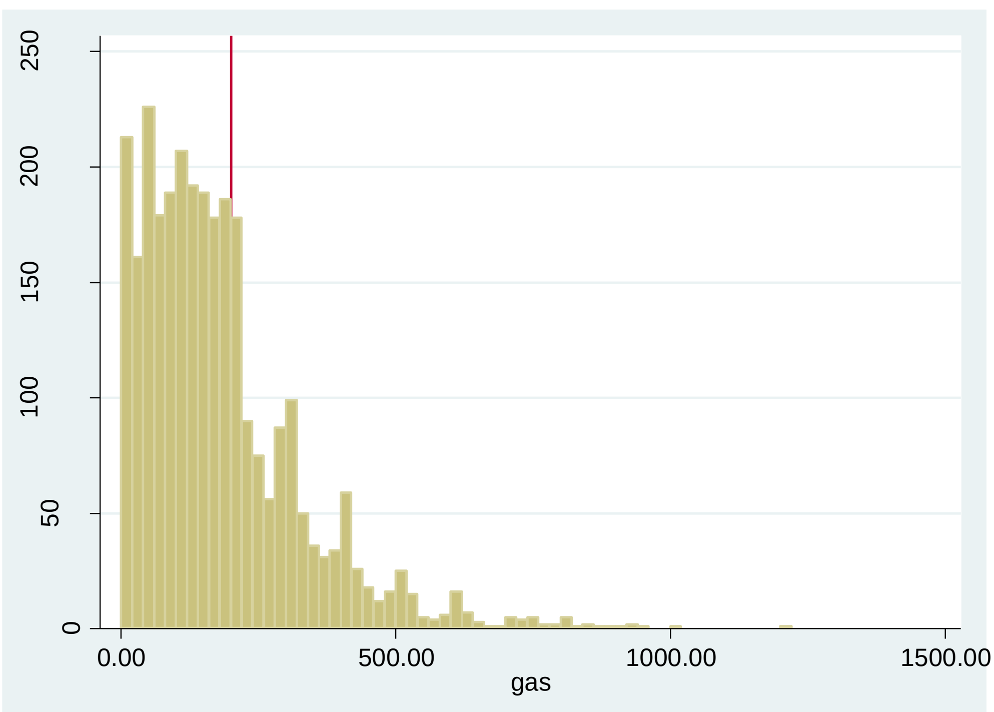


Table 1. Natural gas tariffs for residential customers in Ukraine.

	Unit	2010 Aug 1 to 2014 Apr 30	2014 May 1 to 2015 Mar 31	2015 Apr 1 to 2016 Apr 30	2016 May 1 to 2017 Mar 31	from 2017 April 1
upper bound of block 1	m^3 a year	2,500	2,500	200 a moth	NA	NA
upper bound of block 2	m^3 a year	6,000	6,000	NA	NA	NA
upper bound of block 3	m^3 a year	12,000	NA	NA	NA	NA
variable cost 1 with meter	UAH per m^3	0.7254	1.089			
variable cost 2 with meter	UAH per m^3	1.0980	1.788			
variable cost 3 with meter	UAH per m^3	2.2482	3.645			
variable cost 4 with meter	UAH per m^3	2.6856				
use gas for cooking and/or water heating in *multifamily* buildings, with meter	UAH per m^3		1.182			
variable cost 1 without meter	UAH per m^3	0.7980	1.197			
variable cost 2 without meter	UAH per m^3	1.2078	1.965			
variable cost 3 without meter	UAH per m^3	2.4732	4.011			
variable cost 4 without meter	UAH per m^3	2.9541				
use gas for cooking and/or water heating in *multifamily* buildings, without meter	UAH per m^3		1.299			
use gas for individual heating or cooking and/or water heating (May 1 – Sept. 30), households without gas heating (whole year)	UAH per m^3			7.188		
variable cost 1 - use gas for individual heating or cooking and/or water heating (Oct. 1 – Apr. 30)	UAH per m^3			3.600		
variable cost 2 - use gas for individual heating or cooking and/or water heating (Oct. 1 – Apr. 30)	UAH per m^3			7.188		
gas for all residential users (unit price for all households users, regardless of quantity used and/or conditions of consumption)	UAH per m^3				6.879	6.958

Note: Tariffs include VAT.

Table 2. Sampling frame.

2016 Survey	2017 Survey
• N=500 households • Sample was representative of the stock of housing • Energy bills from Jan 2013 to Apr 2016 • Max T=40	• N=500 households • N=250 Choice-based sampling – wall insulation visible from the outside • N=250 representative of the stock of housing • Energy bills from Jan 2013 to Apr 2017 • Max T=52

Table 3. Survey Response Rates.

	Wave 1	**Wave 2**
total contact attempts	959	802
address not found	16	20
unable to access building	77	11
no response at door	182	94
ineligible (renters)	53	42
total invalid or failed contacts	328	167
Valid contacts made	631	635
declined to participate	108	117
completed questionnaires	500	500
bad questionnaires	23	18
Response rate out of valid contacts	79.24%	78.74%

Table 4. Descriptive Statistics by Wave. Mean or percentage of the sample.

	Wave 1	**Wave 2**
A. Dwelling and Household		
Type of home		
– Single family home	39.8%	35.2%
– Apartment in multi-family building	56.8%	61.4%
– Rowhome	3.4%	3.2%
Size of the home (m^2)	79.95	78.34
Year built	1976	1978
Main heating fuel		
– Natural gas	73.0%	72.0%
– Electricity	15.8%	21.2%
– Solid fuels	8.8%	6.0%
Monthly household income (UAH)	5,063	6,457
B. Energy Efficiency Upgrades Related to Space Heating Done in the Last 3 Years		
Cavity wall or attic insulation	10.6%	36.8%
Double-glazed windows	19.6%	30.5%
Triple-glazed windows	2.2%	3.8%
Basement	n/a	2.2%
Hot water pipes	1.6%	1.2%
Boiler replacement	5.1%	9.2%
Any of the above	31.0%	54.6%
C. Monthly Energy Statistics		
Gas consumption (m^3)	139.60	142.77
Gas benefits – percentage of the sample	7.50%	5.04%
– allowance (m^3/month)	280.7	159.6
Gas subsidies – percentage of the sample	0%	27.8%

Table 5. Non-renovators v. Renovators: Characteristics of the dwelling and natural gas consumption and price. Mean or percent of the sample (standard deviation in parentheses).

	No space-heating EE upgrades since January 2013	Did space-heating EE upgrades since January 2013	T test of the null that the means are the same[a]
A. Dwelling Characteristics			
Size of the home in square meters	78.00 (51.76)	80.68 (49.51)	-0.83
Dwelling is a unit in a multifamily building	59.61%	58.41%	0.38
Dwelling is a single-family home	36.19%	39.25%	-0.99
Year built	1977.32	1977.38	-0.04
Gas heat	74.12%	68.86%	1.48
Electric heat	15.38%	22.66%	-2.88***
B. Natural Gas Consumption and Prices			
Monthly usage (cubic meters)	139.69 (46.56)	143.52 (170.91)	-1.78*
Monthly usage during the heating season (Oct.-Apr.) (cubic meters)	178.10 (157.20)	186.97 (192.23)	-2.99***
Monthly usage during the non-heating season (May-Sept.) (cubic meters)	69.21 (88.75)	65.41 (72.99)	2.11**
Marginal price (April 2016 UAH)	4.13 (2.58)	4.59 (2.53)	-7.26***
Receives benefits for at least part of the sample period	10.14%	8.64%	0.73
Receives subsidies for at least part of the sample period	11.01%	16.12%	-3.00***

*, **, and *** denote statistical significance at the 10%, 5% and 1% level, respectively.
[a] The test assumes unequal variances.

Table 6. Descriptive Statistics: Weather.

	No. obs.	Mean	Standard Deviation	Min	Max
Share of the time during the billing period with no wind	25,604	0.275	0.228	0	0.75
Share of the time with no clouds	25,604	0.145	0.208	0	0.875
Share of the days during the billing period with humidity between 25% and 75%	25,604	0.527	0.499	0	1
Share of the days during the billing period with humidity above 75% but less than 92%	25,604	0.353	0.478	0	1
Share of the days during the billing period with humidity above 92%	25,604	0.121	0.326	0	1
Number of days during the billing period with outdoor temperature of 30° C or more	25,604	2.737	5.351	0	20
Number of days during the billing period with outdoor temperature of 0° C or less	25,604	8.332	9.432	0	31
Heating degree days during the billing period	25,604	449.45	364.082	1	1,374

Table 7. Results from OLS regression of Δln gas demand on controls and Δln marginal price.

	Coefficient (t stat.)
Δln marginal price	0.0460 (1.77)
Δln subsidy	0.0200 (1.28)
Received subsidy but exact amount n/a (dummy) × heating season (dummy)	0.1184 (0.52)
Number of observations	12,763
Number of households	512

Note: The regressions include household fixed effects, period fixed effects, month fixed effects, weather variables, vintage of the dwelling-by-heating season, above median income-by-month effects, SF home-by-month effects. The model is estimated in the first differences. T statistics in parentheses. The t statistics are based on standard errors clustered at the household level. The sample includes only those households in both wave 1 and wave 2 that did not do EE upgrades during the study period.

Table 8. Short-run elasticities. Results from 2SLS estimation of Δln gas demand.

	(A) All	(B) Above median income	(C) Below median income	(D) Multi-family building	(E) Single-family or semi-detached home
SR price elasticity (t statistic)	-0.1643 (-5.56)	-0.0788 (-1.76)	-0.2044 (-4.32)	-0.1294 (-3.46)	-0.2247 (-4.67)
Log subsidy	0.0208 (1.31)	0.0284 (1.58)	-0.0057 (-0.18)	0.0177 (0.70)	0.0417 (1.39)
Received subsidy but exact amount n/a × heating season	0.1363 (0.62)	-0.0109 (-0.04)	0.2682 (0.90)	0.5380 (10.17)	-0.1803 (-0.54)
Effective F statistic	257.85	n/a	n/a	154.55	n/a
Number of observations	12,726	5,944	5,667	7,533	5,193
Number of households	512	237	231	305	207

Note: The regressions include household fixed effects, period fixed effects, month fixed effects, weather variables, vintage of the dwelling-by-heating season, above median income-by-month effects, SF home-by-month effects. The excluded instruments are the log tariffs in each block, log gas allowance, and log percent discount on the regular (the discount is received only if the respondent receives “benefits”). The model is estimated in the first differences. T statistics in parentheses. The t statistics are based on standard errors clustered at the household level. The sample includes only those households in both wave 1 and wave 2 that did not do EE upgrades during the study period.

Table 9. Short-run elasticities: Subsamples based on whether EE renovations were done *before* the beginning of the study period. Results from 2SLS estimation of Δln gas demand.

	(A) no EE upgrades since January 2013, but some done 1-7 years before January 2013	(B) no EE upgrades since January 2013, and no EE upgrades 1-7 years before January 2013
SR price elasticity (t statistic)	-0.1458 (-4.30)	-0.2330 (-3.94)
Log subsidy	0.0163 (0.79)	0.0380 (1.73)
Received subsidy but exact amount n/a × heating season	0.1100 (0.51)	--
Number of observations	357	155
Number of households	8930	3796

Note: The regressions include household fixed effects, period fixed effects, month fixed effects, weather variables, vintage of the dwelling-by-heating season, above median income-by-month effects, SF home-by-month effects. The excluded instruments are the log tariffs in each block, log gas allowance, and log percent discount on the regular (the discount is received only if the respondent receives "benefits"). The model is estimated in the first differences. T statistics in parentheses. The t statistics are based on standard errors clustered at the household level. The sample includes only those households in both wave 1 and wave 2 that did not do EE upgrades during the study period.

Table 10. Short-run elasticities. Results from 2SLS estimation of Δln gas demand, by season and time window.

	Heating season only	Non-heating season only	Jan 2014 to Sept 2016	3 months before + 3 months after the tariff changes	4 months before + 4 months after the tariff changes
SR price elasticity (t statistic)	-0.1472 (-4.16)	-0.1411 (-1.11)	-0.2135 (-4.87)	-0.1470 (-2.19)	-0.1513 (-3.54)
Log subsidy	0.0242 (1.48)	0.0101 (0.52)	0.0444 (1.44)	0.0417 (1.37)	0.0512 (1.64)
Received subsidy but exact amount n/a × heating season	0.0238 (1.48)	0.2785 (1.43)	0.1233 (0.52)	0.1007 (0.38)	0.1051 (0.40)
Number of observations	8,147	4,579	9,872	5,198	6,920
Number of households	512	511	512	512	512

Note: The regressions include household fixed effects, period fixed effects, month fixed effects, weather variables, vintage of the dwelling-by-heating season, above median income-by-month effects, SF home-by-month effects. The excluded instruments are the log tariffs in each block, log gas allowance, and log percent discount on the regular (the discount is received only if the respondent receives "benefits"). The model is estimated in the first differences. T statistics in parentheses. The t statistics are based on standard errors clustered at the household level. The sample includes only those households in both wave 1 and wave 2 that did not do EE upgrades during the study period.

Table 11. Placebo test. Results from 2SLS estimation of Δln gas demand.

	Estimate
SR price elasticity	-0.1407 (-4.81)
log tariff for 1st block in the next period	0.00055 (-0.24)
log tariff for 2nd block in the next period	0.0495 (0.97)
log tariff for 3rd block in the next period	0.0246 (0.94)
Wald test that the coefficients on the three future log tariffs are all zero (p value)	5.75 (0.1243)
Number of observations	12,214
Number of households	512

Note: The regressions include household fixed effects, period fixed effects, month fixed effects, weather variables, vintage of the dwelling-by-heating season, above median income-by-month effects, SF home-by-month effects. The excluded instruments are the log tariffs in each block, log gas allowance, and log percent discount on the regular (the discount is received only if the respondent receives "benefits"). The model is estimated in the first differences. T statistics in parentheses. The t statistics are based on standard errors clustered at the household level. The sample includes only those households in both wave 1 and wave 2 that did not do EE upgrades during the study period.

Table 12. Short-run elasticities: The effect of Salience and Attentiveness Potential. Results from 2SLS estimation of Δln gas demand.

	Correctly estimate winter usage	Overstate winter usage	Heavy users (>224 m^3 a month)	Light users (<224 m^3 a month)	Gas meters inside the home	SF home and gas meter is inside
SR price elasticity	-0.1297 (-3.55)	-0.2315 (-5.05)	-0.1995 (-3.21)	-0.1573 (-4.86)	-0.1566 (-5.17)	-0.1739 (-3.43)
Log subsidy	0.0445 (1.60)	0.0043 (0.22)	0.0079 (0.39)	0.0265 (1.28)	0.0218 (1.31)	0.0087 (0.57)
Received subsidy but exact amount n/a × heating season	-0.2664 (-3.13)	0.1620 (0.77)	0.0690 (0.26)	0.2599 (0.96)	0.2675 (1.26)	0.1750 (0.69)
Number of observations	4,863	6,908	3,362	9,364	11667	3845
Number of households	204	264	124	388	463	146

Note: The regressions include household fixed effects, period fixed effects, month fixed effects, weather variables, vintage of the dwelling-by-heating season, above median income-by-month effects, SF home-by-month effects. The excluded instruments are the log tariffs in each block, log gas allowance, and log percent discount on the regular (the discount is received only if the respondent receives “benefits”). The model is estimated in the first differences. T statistics in parentheses. The t statistics are based on standard errors clustered at the household level. The sample includes only those households in both wave 1 and wave 2 that did not do EE upgrades during the study period.

Appendix

Figure A.1. Share of gas bills available each month of the study period.