Price perception and electricity demand with nonlinear tariffs*

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April 2016

PRELIMINARY DRAFT

Abstract

Increasing block tariffs for electricity and water provide a subsidy for low users and a conservation incentive for high users. However, their effectiveness may depend on both how well consumers understand the nonlinear structure and how attentive they are to consumption. We develop a novel price elicitation instrument to recover these components of price perceptions and apply the instrument to an electricity tariff introduced in Kyrgyzstan in late 2014. We document considerable heterogeneity in understanding of the new price structure. The households with the best understanding of the tariff had the largest reduction in their electricity consumption. However, this effect was driven by those households who were inattentive to their own position on the price schedule. The results suggest that providing consumer-specific information about the effect of new nonlinear tariffs might enhance their political acceptability.

*We are grateful for comments from attendees at the SITE Workshop, UM/MSU/WMU Energy and Environment Day, and the Heartland Workshop, as well as seminar participants at Clemson University, ITAM, PUC-Chile, University of Calgary, University of Chicago Booth, University of Maryland, and the University of Michigan. We appreciate generous financial support from the University of Michigan Office of Research (UMOR), Weiser Center, and the Michigan Institute for Teaching and Research in Economics (MITRE). All errors are our own.

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1 Introduction

Nonlinear tariffs, such as increasing block prices (IBP), are widely used for electricity, water, internet, and phone service rates. Under an IBP, a lower marginal price is set for some basic level of consumption and a higher marginal price is set for consumption in excess of that amount. Such tariffs are typically designed to provide access to a "lifeline" quantity for poor households, while providing conservation incentives for consumers with higher usage. For a consumer facing an IBP, the perceived marginal price of their consumption will be based on both knowledge of the price schedule and attentiveness to their own consumption quantity within the billing period.

Determining the optimal response to nonlinear price schedules can be costly for consumers, as it requires effort to both learn about the price schedule and pay attention to consumption. The costs and benefits of learning about complex tariffs and being attentive to consumption will differ across consumers, resulting in heterogeneity in consumers' perception of the prices that they face.[1] Although both knowledge and attention are essential components of the demand response to nonlinear pricing, there has been little research to parse the contribution of these factors to price perception.

We develop a price elicitation instrument to directly measure two components of residential consumer perception of a nonlinear tariff: knowledge of the tariff and attention to consumption (relative to the price schedule). To measure tariff knowledge, respondents estimate bill amounts at different quantities along the price schedule. We use these to calculate implied marginal prices and classify respondents into categories based on their knowledge of the pricing structure. To measure attention to consumption, respondents estimate the marginal price of consuming additional service, providing information on their perceived pricing tier. We implement the price elicitation instrument in conjunction with a household survey and then match these to monthly electricity consumption data. By combining these datasets, we can study how tariff knowledge and attentiveness are correlated with demand responses to nonlinear tariffs.

The empirical application for our price elicitation instrument is an electricity tariff reform in Kyrgyzstan that began in December 2014. This reform replaced the previous uniform tariff with a two-tier IBP. While the price on the first tier (below 700 kWh per month) did not change, the price on the second tier increased to nearly three times higher. Starting three

[1]For example, for people with high costs, it may be optimal to remain uninformed about the true price structure, and observed consumption may differ from what would be expected for fully informed consumers. Sallee (2014) illustrates that paying limited attention when making some purchases may be rational.

months after the tariff introduction, we implemented our price elicitation exercise in conjunction with a household energy survey that was completed by more than 1800 households in northern Kyrgyzstan.

Our results show strong evidence of heterogeneity in knowledge of the tariff, even amongst respondents who were aware of the tariff reform.[2] The majority of households provided responses consistent with the nonlinearity in the new tariff at 700 kWh. However, most respondents underestimated the effect of the new tariff on the total bill amount at levels of consumption above the discontinuity, consistent with not understanding the tariff structure. For example, less than 20 percent of respondents correctly calculated the total bill (to within 10 percent of the true value) at 2000 kWh.

The heterogeneity in tariff knowledge correlates with heterogeneity in response to the nonlinear price. Knowledge of the price structure predicts electricity consumption behavior following the tariff reform. Households with the greatest tariff knowledge (corresponding to reporting a price schedule closest to the true price schedule) were more responsive to the new tariff.

Using our measure of attention to consumption, we split these results by attentive and inattentive consumers. We find the reductions in electricity consumption are largely driven by the respondents who are inattentive to their consumption (and therefore their location on the tariff schedule). Tariff knowledge has a significant effect only for inattentive respondents who do not know where their consumption places them on the tariff schedule. For attentive respondents, who know the pricing tier they are on, knowledge of the exact tariff has little effect on consumption. The interpretation of this result is that consumers who know about the high second tier price for the new tariff, but do not realize that this has little effect on their own cost of using electricity, will have the largest consumption response relative to the change in their expected marginal price.

Our results are consistent with those of Kahn and Wolak (2013), who implement a randomized experiment in California to provide consumer-specific information about the IBP structure. In their setting, informing low tier consumers that they were on the lower price tier led to an increase in the consumption of those households. Similarly, in our setting, the IBP had the largest effect on consumption for the low tier consumers who did not realize that they were on the low tier.

The assumption that consumers are fully informed and attentive is increasingly called

[2] Only respondents who reported knowing about the new tariff were asked to complete the price elicitation instrument. Therefore, all of our price elicitation results are for the subsample of respondents who, at a minimum, were aware that tariffs had recently changed.

into question.[3] For example, Grubb (2015) shows that consumers of cellular phone services who are informed of their service plan yet inattentive to past usage, may still be uncertain of the marginal price that they face and therefore may experience "bill shock" at the end of the billing period.

The existing literature on price perceptions and electricity demand, including Shin (1985), Borenstein (2009), and Ito (2014), has suggested that consumers do not respond to complex electricity prices in the way that simple theory might predict. These papers are based on the premise that if information regarding marginal price is costly, then consumers may not equate benefits and costs at the margin (Shin, 1985). However, the design of these existing studies means that they are not able to directly measure the components of the perceived price for individual consumers, nor examine heterogeneity in perceived price across different categories of consumers.

Our price elicitation instrument allows us to make several contributions to the literature on consumer responses to nonlinear price schedules. We develop independent measures of the components of perceived price—tariff knowledge and attentiveness to consumption—rather than estimating an aggregated perceived price. There is little previous work on heterogeneity in the perception of nonlinear tariffs, and our approach means we can directly measure the relationship between price perceptions and electricity consumption. Finally, by combining the price elicitation instrument with detailed survey data on household characteristics, we can control for additional factors that affect electricity demand.

Our work is analogous to recent work in other fields that combines standard demand estimation methods with survey instruments to directly measure consumer knowledge and other factors that might affect demand. For example, most work on the demand for health insurance plans has identified demand parameters using administrative data on insurance plan choices and the actual risk realizations.[4] Similar to our approach, Handel and Kolstad (2015) develop a survey tool to directly measure information frictions and hassle costs, allowing them to separate these from other unobserved demand factors. They combine this with administrative data to separately identify the role of information frictions and risk preferences in determining insurance plan demand.[5]

[3]For a review of the literature on consumer inattention to complex pricing, see DellaVigna (2009). Studies about the role of consumer inattention and imperfect information in purchase decisions address tax-inclusive posted prices (Chetty, Looney and Kroft, 2009), insurance premiums (Abaluck and Gruber, 2011), and energy efficiency (Allcott and Taubinsky, 2015), amongst many others.

[4]Examples of such micro estimates of health insurance choice include Handel (2013), Abaluck and Gruber (2011), Einav et al. (2013), Bundorf, Levin and Mahoney (2012), among others.

[5]Another analogous application is Karlan (2005), who uses an experiment to develop trust measures

Our field work provides a rich measure of the initial formation of perceptions of a new nonlinear tariff, in a setting where such a tariff had not previously been used for electricity pricing. In our analysis, we study the correlation between tariff knowledge, attentiveness to consumption, and the short-term consumption responses to the new tariff. However, we do not induce experimental variation in tariff knowledge and awareness of consumption (as in Kahn and Wolak (2013)) nor do we have quasi-experimental variation in the nonlinear price structure (as in Ito (2014)). Therefore we do not interpret our results as direct evidence of a causal relationship between our measure of price perceptions and electricity consumption. Our results cannot rule out the potential for reverse causality, such as exogenous shocks to electricity demand providing information to households about the structure of the new tariff schedule, or greater investment in learning about the new tariff by inattentive households with more elastic electricity demand.

Our analysis of price perceptions also helps to understand the distributional effects and political feasibility of implementing nonlinear tariffs. In many developing countries, low utility revenues result in a lack of investment in new infrastructure and insufficient maintenance of existing infrastructure. Poor tariff and subsidy design can result in the persistence of low quality service (McRae, 2015), which is of particular concern give the social and economic importance of electricity and water.[6] Although the necessity of tariff reform in developing countries is widely acknowledged, attempts to enact price changes are often met by resistance and protest. In theory, an IBP may be more politically feasible than alternative tariff options, because it provides a cheaper price to consumers with low usage, who are often the poorest households. The higher marginal prices paid by the high-use consumers generate the income required for infrastructure maintenance and expansion. In practice, the success of tariff reform will depend on perceptions of the nonlinear price structure. In particular, inattentive consumers who know about higher prices on the new tariff, but do not realize that they are not on the high price tier, might have an unreasonably negative perception of the tariff reform.

The paper proceeds as follows. Section 2 provides details on the institutional setting and the price elicitation instrument. Section 3 describes the data collection process. Section 4 provides descriptive evidence on the heterogeneity in tariff knowledge and the construction

among FINCA members in Peru, then analyzes whether the trust measure predicts later financial outcomes among participants.

[6]Papers on the impact of improved electrification include Dinkelman (2011), Lipscomb, Mobarak and Barham (2013), and Rud (2012). Impacts of water infrastructure are addressed in Duflo and Pande (2007), Devoto et al. (2014), Kremer et al. (2011), and Meeks (2014).

of our knowledge and attentiveness measures. These are used in Section 5 to analyze the relationship between tariff knowledge and attentiveness and the demand response to the price change. Section 6 discusses distributional effects of nonlinear pricing in this context. Section 7 concludes.

2 Price Elicitation Instrument and its Application

2.1 Institutional setting

Kyrgyzstan provides an ideal setting in which to apply our price elicitation instrument. Due to large-scale infrastructure construction during the former Soviet Union, Kyrgyzstan has a high rate of electrification, with nearly 100 percent of households connected to the electrical grid (Gassmann, 2012). Similar to other developing countries, residential electricity prices in Kyrgyzstan are very low. These prices had remained fixed in nominal terms since 2008 at 0.7 Kyrgyz som per kWh (equivalent at current exchange rates to 1.2 U.S. cents per kWh).[7]

A number of challenges result from low electricity prices. First, the domestic power sector has been operating at a loss. In 2013, the loss per kWh sold was estimated at 0.36 Kyrgyz soms. The lack of an increase in the residential electricity tariff resulted in the power companies operating with an annual deficit of approximately 2-3 billion Kyrgyz soms. The shortage of funds resulting from these chronic operating losses prevent sufficient repair, modernization, and construction of new facilities (Medium-term Electricity Tariff Policy, 2014). Given all 16 of the existing hydropower plants were constructed during the former Soviet Union[8] and the additional generation is provided by old and inefficient thermal units (Zozulinsky, 2007), the country's electric utilities are challenged to meet the growing demand for electricity.

The low prices also lead to excessive use of electricity, particularly during the winter heating months. Because electricity is cheaper than coal, many households have switched to the former for heating, and newer houses are often constructed specifically to rely on electricity for heating. There is insufficient generation capacity to meet peak demand, giving the government an unpalatable choice between rolling blackouts and expensive imported electricity. To address the supply constraints in winter 2014-2015, the government imported

[7] Prior to 2014, the only variation in these rates occurred during the first three months of 2010, when rates doubled to 1.5 som/kWh. This rapid price rise was perceived by many to have contributed to political unrest that year. After the unrest, the price was reduced to its previous level.

[8] 90 percent of the country's power generation is hydroelectric.

electricity from Kazakhstan. The price for the imported electricity was 5.17 som/kWh, more than seven times higher than the residential price prior to fall 2014.

2.2 Introduction of a non-linear price schedule

Given the continued growth in electricity demand for heating in winter, the substantial shortfall in generation capacity, and the high cost of imported electricity, the Kyrgyz government introduced a new medium-term tariff policy in 2014. The main objectives of the policy were to ensure both financial sustainability of the country's energy sector (including eliminating the cross subsidies in the tariff) and a stable power supply. The Ministry of Energy expected that the introduction of the new electricity tariff would encourage efficiency in electricity use and the adoption of energy saving technologies and alternative heating sources.

In September 2014, prices increased by 70 percent for households with 3-phase electricity connections, which are typically used by the largest electricity consumers. This price change was challenged in the courts. As an alternative, starting in December 2014, a two-tier increasing block price schedule was introduced for all residential consumers (Figure 1).[9] All consumption below 700 kWh/month continued to be charged at the same rate of 0.7 som/kWh. Consumption above 700 kWh/month was charged at a rate that is nearly three times higher: 2.05 som/kWh. Later in the winter there was a small decrease in the marginal price on the second tier.

2.3 Price elicitation instrument

We developed a new survey instrument to measure two components of a consumer's price perception: (1) the respondent's knowledge of the price schedule and (2) the respondent's attentiveness to electricity consumption (and therefore awareness of where the household is on the price schedule). The price elicitation instrument was administered to all survey respondents that replied affirmatively to the question of whether they were aware of a recent tariff change. The full English translation of the price elicitation instrument is included as an Appendix.[10]

The first component of the price elicitation instrument tests knowledge of the new price schedule. Respondents were asked to estimate the total amount of the electricity bill in

[9]The price change was announced November 25 and took effect on December 11.

[10]The instrument was piloted extensively with households prior to the study onset. Respondents were asked to complete the worksheet on their own. The instrument was developed to be appropriate for the survey sample, given the high levels of education, literacy, and numeracy in the country's adult population.

2015, for four different consumption quantities, after being provided information on the bill amount for each quantity under the old prices. Quantities were selected to be below, at and above the quantity on the first tier: 400 kWh (on the first tier), 700 kWh (at the kink point), and 1000 and 2000 kWh (on the second tier). The design of the graphic highlighted that consumption quantity was the same for the two years.

To supplement those four price questions, the instrument also tests basic knowledge of the price schedule via two multiple choice questions. The first question asks about the quantity of electricity that can be consumed on the first tier of the new tariff (700 kWh). The second question asks the respondent for the price on the second tier of the new tariff (2.05 soms/kWh). Correct answers to these questions indicate some exposure to information about the new tariff, but do not necessarily mean that respondents understand how electricity bills are calculated.[11]

In second component of the price elicitation instrument, we asked two questions to assess the respondent's attentiveness to consumption, which determines the point at which they are located on the price schedule. Respondents were told the cost of running an electric light bulb for an additional four hours each day, based on the electricity prices in 2014.[12] They were then asked to estimate the cost for their household of the same additional light bulb use, based on the electricity tariff in 2015. The second question was similar, but instead asked for the cost of running an electric heater for an extra four hours each day. For both questions, we can convert the responses into an implied marginal price of electricity.

3 Data and sampling

3.1 Data

We implemented a household survey soon after the introduction of the IBP, starting in March 2015. The survey was designed to collect information for a detailed analysis of the household response to the price change, including household demographics, dwelling characteristics, home appliances, energy-related behaviors, and respondent opinions about the new electricity price schedule.[13] The survey collected information on several categories

[11]These questions were placed at the end of the instrument, as we did not want the multiple choice questions to influence responses for the other components.

[12]Because the tariff was uniform in 2014, the marginal costs were previously identical for everyone.

[13]At the outset of the survey, surveyors asked to speak to the adult in the household who is responsible for energy-related decisions. If that person was not home, surveyors asked permission to return when that person would be available. The respondent was provided a monetary incentive for the time spent completing

of energy-related behavior, including heating, cooking and water heating, for the winter concluding at the survey time (winter 2015). The survey also included recall questions on these behaviors for the previous year (winter 2014) to establish a baseline prior to the change in the electricity price.

The cross-sectional data collected via the survey instrument can be matched with household-level billing data that provides monthly electricity consumption from October 2010 to March 2015. These billing data include information on the meter type and the transformer serving the house, as well as the number of days and electricity consumption within a given monthly billing cycle. The panel provides four years of monthly data on "baseline" household electricity consumption under the previous uniform tariff, when the electricity price remained constant at 0.70 Kyrgyz soms per kWh. We match the billing data with monthly measures of heating and cooling degree days. These were calculated using daily temperature data from two nearby weather stations.

3.2 Sampling method

Households within one district in northern Kyrgyzstan served as the target population for the study. Given that nearly all houses are served by formal electricity connections, the list of more than 40,000 households with service through the electricity utility includes almost all houses in that region.[14] The sampling cluster was the electricity transformer serving a neighborhood. A random sample of 192 transformers was selected with probability of selection proportional to the number of households at the transformer. Within these transformers, we selected a random sample of 14 households.[15] Households with more than one missing or zero observation in the year prior to the electricity price change (between November 2013 and November 2014) were dropped from the selection process. This two-stage design resulted in the selection of a random sample of 2,688 households across 192 transformers.

There were 819 households who did not respond to the survey, resulting in a sample size of 1869 households (a 69.5 percent response rate). The majority of this non-response was due to an inability to locate or access the household or lack of response at the home. Comparing electricity consumption of the non-respondent households with the full sample

the survey.

[14]Neighborhoods in which we piloted the survey were dropped prior to the random sampling stage.

[15]We followed Groves et al. (2011) for a method through which to deal with clusters that are either too large or too small. For the purpose of sample selection, transformers with a large number of households (i.e. greater than the total number of households / 192) were split into three new artificial transformer codes. Transformers with fewer than 14 households were combined with one or two other small transformers in the same village to create an artificial transformer code.

shows these two groups are very similar (Table 1). Not all survey respondents completed the price elicitation worksheet, as some were unwilling to attempt or unable to finish the exercise. The sample includes 1495 households who completed both the survey and the bill computation questions of the price elicitation instrument.

4 Heterogeneity in Tariff Knowledge and Attentiveness

The price elicitation instrument and household survey capture a broad set of measures of respondents' knowledge of the new nonlinear tariff and their attentiveness to where their consumption lies on the price schedule. To study how heterogeneity in knowledge and attentiveness affects our outcomes of interest, we aggregate these measures to construct a small number of knowledge and attentiveness groups. Using multiple methodologies for constructing these aggregate groups demonstrates that our results are not determined by a particular choice of aggregation procedure.

4.1 Descriptive evidence

The two multiple choice questions in the price elicitation instrument measure basic familiarity with the new tariff schedule. Over two thirds of respondents (67 percent) recognized the quantity threshold of 700 kWh for the higher price (Column 2 of Table 2). A smaller proportion of respondents (37 percent) recognized the price on the second tier of the new tariff.

Knowledge of the quantity and price parameters of the new tariff was higher in more urban areas, particularly in towns with more than 1000 households. 79 percent of respondents in the largest towns recognized the 700 kWh threshold, compared to 52 percent of respondents in the smallest villages. Respondents with higher incomes and higher education levels were somewhat more likely to answer these questions correctly. There was little difference by the age and sex of the respondent.

We calculate several summary measures based on the bill totals that the respondents estimated for four different consumption levels (Figure 2). The first of these is the difference between the reported and the correct bill amount, expressed as a percentage of the correct bill amount. For a consumption level of 700 kWh, 77 percent of respondents estimated a bill total within 10 percent of the correct value (Column 4 of Table 2). This shows that most respondents were aware that the new tariff did not affect electricity bills at low levels of consumption.

Estimates of the bill total were increasingly inaccurate at higher levels of consumption. 36 percent of respondents provided a correct answer at 1000 kWh and 19 percent did so at 2000 kWh (Columns 5 and 6 of Table 2). Respondents who had electricity consumption above the quantity threshold in the previous winter were more likely to answer correctly at 2000 kWh: 22 percent for those with consumption above 700 kWh compared to 14 percent for those with consumption below 700 kWh. Similar to the pattern for the tariff knowledge questions, respondents in urban areas were much more likely to answer the bill questions correctly. There was a small effect by education and income, but no difference by demographic group.

We also use the reported bill totals to calculate the implied marginal price at different points on the tariff schedule (Figure 2). Let q_k be the monthly consumption quantity and B_k^R the respondent's estimate of the bill amount at q_k. The respondent's calculation of the marginal price between q_{k-1} and q_k is given by (1):

$$\hat{p}_k^C = \frac{B_k^R - B_{k-1}^R}{q_k - q_{k-1}} \tag{1}$$

We compare these implied marginal prices to the marginal prices that respondents faced in January 2015, based on their actual level of electricity consumption that month.

Most respondents with consumption below the 700 kWh threshold had an implied marginal price equal to their true marginal price (top left graph of Figure 3). This is a restatement of the earlier result that most respondents recognized that the bill totals at 400 kWh and 700 kWh did not change. For respondents with consumption above the 700 kWh threshold, there is bunching of bill responses at the true marginal price (top right graph). However, the implied marginal price for most respondents was below their true marginal price. The mean marginal price implied by the reported bill totals (1.44 soms/kWh) is 70 percent of the true value for these respondents.

As described above, our price elicitation instrument included two questions designed to explicitly measure the marginal electricity price perceived by respondents. There is considerable heterogeneity in the perceived marginal price. For respondents with electricity consumption placing them on the low tier, the modal perceived marginal price is the true marginal price of 0.70 soms/kWh (left, bottom and middle graphs on Figure 3). However, a large number of respondents perceived a marginal price higher than their true marginal price. For respondents on the high tier, the modal response was the marginal price on the low tier. Very few respondents calculated a marginal price close to their true marginal price of 2.05 soms/kWh.

The mean marginal prices from the two marginal price elicitation questions were similar in magnitude to the implied marginal prices from the bill total questions. This suggests that the major difficulty for respondents was not the interpretation of the question or the computation of the marginal prices, but instead knowing their own consumption in January 2015 and where this would place them on the tariff schedule.

4.2 Construction of tariff knowledge groups

Our price elicitation instrument captures multi-dimensional heterogeneity in consumer knowledge and understanding of the new electricity price schedule. In order to analyze the effects of this heterogeneity on our outcomes of interest, we construct alternative measures to summarize the perceived price.

Our primary measure is based on the implied marginal prices from the four reported bill schedule questions. For each marginal price calculated for respondent i, we calculate the percentage difference from the true marginal price and sum over these percentage differences:

$$M_i = \sum_{k=1}^{3} \frac{\hat{p}_{ik}^{C} - p_k}{p_k} \tag{2}$$

where $\hat{p}_{ik}^{C}$ is the marginal price for respondent i on segment k calculated from (1) and p_k is the true marginal price on segment k.[16] We then rank the respondents in order of their M_i and divide the sample into three evenly sized groups, based on terciles of the M_i.

Based on this grouping, the lowest price perception group mostly contains observations of respondents with marginal prices close to the old uniform tariff (Figure 4). The middle price perception group mostly contains respondents who reported some increase in bill amounts at higher consumption quantities, but who still underestimate the size of the bill increase at high consumption levels (Figure 5). Finally, the high price perception group mostly contains respondents who reported close to the true bill increase, even at high consumption levels (Figure 6). In particular, the median reported bill at 2000 kWh for this group exactly matches the true bill amount.

An alternative method to construct price perception groups is to apply clustering algo-

[16] Because each $\hat{p}_{ik}^{C}$ is calculated from the bill estimates B_k^R, this expression simplifies to a linear combination of the B_k^R.

rithms to extract patterns of similar responses from the price elicitation instrument. The simplest approach uses just the two marginal prices from the top tier of the new price schedule. As shown in the top right graph of Figure 3, there are two prices with a particularly large mass of responses: the marginal price for the uniform tariff and the correct marginal price for the new tariff.

Based on this observation, we apply the K-means clustering algorithm to the marginal prices to create two groups: a "low" and a "high" group. For a predetermined K (in this case $K = 2$), the algorithm assigns observations to exactly one group in such a way as to minimize the aggregate Euclidean distance of each point from its group mean (Friedman, Hastie and Tibshirani, 2009). The number of observations in each group is determined by the relative similarity of the responses, rather than using a fixed cutoff as with the tercile calculation. Applying this algorithm generates a "low" group with 939 respondents and a "high" group with 560 respondents (Figure 7).[17]

We report results for one additional categorization from the data. We create is a price knowledge index based only on the answers to the multiple choice questions on the price elicitation instrument about the price and quantity for the new tariff. For this measure, the "low group" is the set of respondents who answered both questions wrong, the "medium group" answered exactly one question correctly, and the "high group" answered both questions correctly.

4.3 Construction of attentiveness groups

We construct a measure of attentiveness using the questions about the respondent's own marginal cost of changing consumption of energy services. In order to separate limited knowledge or computational errors from attentiveness to consumption, we do not rely on the exact numerical values of the marginal prices provided. Instead we define a binary measure, based on whether respondents reported the same marginal price that was provided to them for 2014. This implies that they perceive their consumption as being on the price tier for which the marginal price did not change—the first price tier. If respondents reported a higher marginal price than the one provided for 2014, they perceive their consumption as being on a higher part of the tariff schedule—the second price tier.

A respondent is considered "attentive" if they correctly identify their price tier for either the heating question or the lighting question. If they incorrectly identify their price tier for

[17] Because the algorithm is sensitive to outliers, marginal prices from the reported bills are winsorized at 0 and 4.1 (double the true marginal price).

both questions, they are considered "inattentive". More concretely, an attentive respondent is either (i) on the top tier in January 2015 and reported a higher marginal price for either the heater or the bulb question, or (ii) on the bottom tier in January 2015 and reported the same marginal price for both questions. Otherwise the respondent is considered inattentive.

We create several versions of this attentiveness measure based on alternative assumptions. Instead of defining the true pricing tier using the respondent's actual consumption in January 2015 (which is one of the outcome variables of interest), we use the respondent's predicted consumption in January 2015 based on a household-specific model estimated using data from before the pricing reforms (see Section 5.1). In another variant of our measure, we require the respondent to correctly identify their price tier for both heating and lighting questions. An incorrect response to either question would be considered "inattentive".

We also use a different version of the attentiveness measure that is independent of the price elicitation responses. In the household energy survey, we asked for the total amount of the electricity bill in January 2014 and January 2015. Using our billing data for January 2015 we calculate the absolute percentage error in the self-reported bill totals. Respondents with a percentage error larger than the median percentage error are labeled as inattentive. Otherwise, the respondents who knew the approximate value of their electricity bill are labeled as attentive.

5 Effect of knowledge and attentiveness on electricity demand

The previous section documented the heterogeneity in tariff knowledge and attentiveness to consumption that we recovered using our price elicitation instrument. In this section we show how these differences in knowledge and attentiveness are correlated with the consumption response to the new nonlinear tariff.

Electricity use in winter 2015, after the introduction of the new nonlinear tariff schedule, was lower than it had been in any winter since 2011. Residential electricity consumption in Kyrgyzstan is highly seasonal, with consumption during winter months about four times greater than consumption during summer. Figure 8 shows the mean consumption from 2010 to 2015 for the three tariff knowledge groups constructed based on the computed marginal prices as in (2). The households with the highest knowledge have higher winter peak consumption than the other households, while summer consumption for the three groups is similar. The difference in consumption between the three tariff knowledge groups was smaller than it had been in winter 2014 and the last two months of 2014. In this section we formalize the analysis of the consumption change that occurred after the introduction of the new tariff.

5.1 Demand model with tariff knowledge and inattentiveness

The demand for electricity of household i in month-of-sample t is given by:

$$\log q_{it} = \alpha_{im} + \beta_g \log p_{it} + f(H_{it}, \delta_{\mathbf{g}}) + \tau_g t + \varepsilon_{it} \tag{3}$$

Here q_{it} is the mean daily electricity consumption in kWh and p_{it} is the marginal price of electricity faced by household i in period t. Index g represents the tariff knowledge and/or attentiveness group of household i. The response to price changes may depend on the household's knowledge of the tariff or attentiveness to their consumption, therefore the price coefficient β_g is indexed by g to allow for variation in price response by group. The term α_{im} is a household-month fixed effect, with variation in α_{im} reflecting differences in appliance holdings and usage patterns across months of the year. Year-to-year variation in weather conditions in a month are captured by the flexible function $f(H_{it})$ of daily temperatures faced by household i in period t. Secular changes in electricity consumption is measured by the time trend τ_g. Both τ_g and the weather effects δ_g may vary by the knowledge and attentiveness groups.

Given the remarkable seasonality in electricity consumption in Kyrgyzstan, it is important to allow for a flexible response of electricity consumption to weather. For our base results, we use cubic polynomials in heating degree days and cooling degree days. As a robustness check, we use the proportion of days each month lying within discrete temperature bins.[18] The temperature responses are allowed to vary by the knowledge and attentiveness groups, to reflect possible group-level variation in building construction, availability of substitute heating sources that do not use electricity, and differences in taste for comfort.

As is well-known, the increasing block tariff creates correlation between the marginal price and the consumption quantity, leading to the anomalous positive coefficient on price (Column (1) in Table 3). We adopt the methodology described by Mansur and Olmstead (2012) for the use of expected marginal prices in the demand estimation. In our data, we observe a long period with constant uniform prices before the introduction of the new tariffs in 2014. We use this pre-reform data to estimate a household-specific demand model given

[18]Both heating degree days and cooling degree days are defined using a base point of 18 degrees Celsius. For the temperature bins, we count the number of days with mean temperature lying within twelve bins, each five degrees Celsius wide, from -25 to 35 degrees Celsius.

by:

$$\log q_{it} = \alpha_i + f(H_{it}, \delta_{\mathbf{i}}) + \tau_i t + \varepsilon_{it} \tag{4}$$

Importantly, because prices are constant throughout the pre-reform data, the price effect β_i is absorbed into α_i.

We estimate this model for each household and use the results to predict the household's consumption for each month after the new tariff introduction. The predicted consumption accounts for the household's response to observed weather conditions in the post-reform months but does not consider any potential price response. Using the predicted consumption and the standard error of the prediction, we calculate the probability of the household being on each quantity step of the new price schedule. The sum of these probabilities, multiplied by the marginal price on each step, gives the expected marginal price for the household in each month. Because the expected marginal price is calculated using only weather data, historical consumption data, and the price schedule, it is not correlated with the contemporaneous error term in household consumption.[19]

Using the expected marginal price in place of the marginal price for the estimation of (3) gives a negative and statistically significant price coefficient (Column (2) in Table 3). Alternatively, we use marginal price and instrument with the expected marginal price (Column 3). The price coefficient for the fixed effects instrumental variables estimation remains negative and is somewhat larger in magnitude, possibly reflecting measurement error from the use of expected marginal price in (2).

By allowing the price effect to vary based on the tariff knowledge group g, we show that the consumption response to the new tariff is larger for those households with greater knowledge of the tariff. The interaction of the middle and high tariff knowledge groups with the price variables is negative and statistically significantly different from zero (Column 4). Using expected marginal price, the implied price elasticity for the low group is -0.24, compared to price elasticities of -0.28 and -0.33 for the middle and high groups. As before, the coefficients are larger in magnitude when we use marginal price and instrument with the expected marginal price and its interaction with the group variables (Column 5). In both columns the excluded group is those households with the lowest tariff knowledge.

For a household facing a nonlinear tariff, the perceived marginal price of their consump-

[19]As a robustness check, we estimate alternative versions of the household-specific model in (4) with the dependent variable in levels instead of logs, and with and without the trend term. Using these alternative models to calculate the expected marginal price has little effect on the final results.

tion depends on both their knowledge of the tariff and their attentiveness to where their consumption places them on the tariff schedule. Table 3 showed results for all households broken down only by their tariff knowledge. Table 4 examines the heterogeneity in the tariff knowledge results, broken down by the household's attentiveness to consumption. Each of the interactions of price with the tariff knowledge groups is further interacted with an indicator variable that is equal to 1 for an inattentive household.

Inattentive households are more responsive to marginal price than attentive households (Columns 2 and 3 in Table 4). The mean price elasticity for attentive households is -0.35, compared to a price elasticity of -0.64 for the inattentive households. This result is almost entirely driven by a very large response to marginal price by the inattentive households who have medium and (especially) high knowledge of the tariff (Column 5 of Table 4). The price elasticity for an inattentive household with high tariff knowledge is -1.10, calculated by adding together the price coefficient with the three interaction terms.

5.2 Robustness checks

Results using the multiple choice questions to measure tariff knowledge are very consistent with the base results using the reported tariff schedule (Column 1 of Table 5). Inattentive respondents who could answer the questions about the second tier price and quantity have a price elasticity of -1.20. For attentive consumers who know their pricing tier, there is no difference between those who answered the multiple choice questions correctly or incorrectly.

The alternative method of defining the price knowledge groups using a clustering algorithm applied to the inferred marginal prices gives a similar result (Column 2 of Table 5). The group of "high" respondents has implied marginal prices from the bill schedule reports that are closer to the true marginal price on the second tier. This group has a large price response even for those who are attentive to their consumption: -0.39 compared to -0.32. For the inattentive consumers, the group with high knowledge has a price elasticity of -0.85, compared to -0.55 for the low knowledge group. The results in Columns 1 and 2 suggest that the findings are not sensitive to the particular method used to define the price knowledge groups.

The results vary little with alternative assumptions for the definition of the attentiveness groups (Columns 3 and 4 of Table 5). Assigning households to pricing tiers using predicted consumption in January 2015, calculated from the household-specific demand model in Equation (4), gives a very similar result. The requirement that the respondents provide the correct pricing tier for both multiple choice questions, instead of just for either question, assigns many more respondents to the “inattentive” category (Column 4). With this alternative definition even the inattentive households with low price knowledge are more price responsive (price elasticity of -0.41 compared to -0.24). The difference between the high and low knowledge groups within the inattentive category is smaller in magnitude than before, but still statistically significant.

The final attentiveness measure is based on how accurately respondents could recall their electricity bills in January 2015. Inattentive respondents, defined as those with the least accurate bill recall, were more price responsive than those with accurate bill recall. Inattentive consumers with the best knowledge of the tariff schedule were again the most price responsive: a price elasticity of -0.64 compare to -0.36 for attentive consumers with the same level of price knowledge.

The results for the price perception groupings are robust to a variety of alternative regression specifications. Replacing the cubic polynomials in heating and cooling degree days with discrete temperature bins gives a result that is even larger in magnitude for the difference between the high and low groups (Column 1 of Table 6). Similarly, the results are robust to estimating the model with no group-specific time trends (Column 2) although this does give a price elasticity for the attentive consumers that is smaller in magnitude than before. Replacing the group-specific time trends with group-specific year indicators (April through March) gives a similar result to earlier (Column 3).

One challenge for interpretation of the results is being able to distinguish between (i) heterogeneity in tariff knowledge and attentiveness to consumption that affected the perceived price on the nonlinear tariff schedule and (ii) heterogeneity in preferences that affects the degree of responsiveness to the perceived price. We provide some supporting evidence that the results reflect differences in knowledge and attentiveness. During the last four months of 2014, the customers with a 3-phase connection were charged a higher uniform tariff. All else being equal, variation in consumer responses between a higher uniform tariff and a higher nonlinear tariff may reflect the differences in perception of price on the nonlinear tariff.

Estimating the model only for the period before the introduction of the nonlinear tariff gives a price coefficient that is slightly smaller in magnitude than the base result (Column 4 of Table 6). This result is based only on within-household variation in price for those households that are placed on the 3-phase tariff. For these households, the interaction terms with the tariff knowledge and inattentive groups are smaller in magnitude than before and statistically insignificant. This supports the idea that the main results are due to differences in understanding of the nonlinear tariff.

Finally, we run a placebo test to check that our results are not driven by a mechanical effect from the way in which our variables are constructed. We take the same tariff changes but shift them back twelve months. For example, the nonlinear tariff from January 2015 is applied to observations in January 2014, and the attentiveness measure is defined using consumption for January 2014. We then estimate the identical model as before, using data through the end of March 2014 with the placebo tariffs. The price effects and the interactions with the perception groupings are all close to zero and (with one minor exception) statistically insignificant.

5.3 Short and long-run price responses

Energy consumers have several options for reducing their consumption in response to a price increase. In the short-run, energy usage can be reduced by limiting consumption of energy services such as lighting and heating. A household using electric heating might heat fewer rooms, heat them for fewer hours of the day, or heat them to a lower temperature. In the long-run, households can make investments to improve the energy efficiency of their dwelling or appliances. This may allow them to maintain the same level of energy service consumption but using less energy. In this section we provide suggestive evidence that the households with better understanding of the tariff schedule were more likely to have invested in energy efficiency improvements to their dwellings. This finding of a long-run response is important because previous studies have found that the consumption response to permanent price changes can be short-lived.

The predominant household use for electricity in Kyrgyzstan is for heating in winter. We can measure heating consumption in several different ways: number of rooms heated, number of hours in which each room is heated, or the temperature to which the room is heated. To develop an objective measure for the last of these, our survey enumerators asked permission to enter the dwelling and measure the ambient room temperature in the living room. The dwellings for the respondents in the highest price knowledge group were the warmest: a mean of 19.4 degrees Celsius, compared to a 18.5 and 19.3 degrees for the low and middle groups. This was despite the dwellings in the high group having the greatest reduction in electricity consumption.

The households with the highest tariff knowledge were more likely to have invested in energy efficiency upgrades for their dwelling (Table 7). After controlling for other observable characteristics, they were 6 percentage points more likely to have any type of insulation in their dwelling. Overall only 11 percent of dwellings have insulation, with richer households,

households with higher electricity consumption in the previous winter, and households with larger dwellings all more likely to have insulation. The households in the high tariff knowledge group were 18 percentage points more likely to have window insulation, 8 percentage points more likely to have CFLs, and 9 percentage points more likely to have a new refrigerator.

Respondents were also asked an open-ended question about upgrades they had made as a result of the price change (Column 5 of Table 7). Overall, 10.9 percent of respondents reported having made an energy efficiency upgrade. After controlling for other observable characteristics, the high group households were 3.6 percentage points more likely to report an upgrade, although this difference is not statistically significant. Larger dwellings, and households with higher electricity consumption in the previous winter, were more likely to upgrade.

6 Price perceptions and distributional effects of non-linear pricing

Tariff reform in public services is essential for many developing countries. Water and electricity services are often subsidized and such subsidies contribute to a cycle of poor infrastructure quality. Low tariff levels result in a lack of investment in new infrastructure or insufficient maintenance of existing infrastructure. Low levels of investment can result in intermittent service or the eventual collapse of that particular service.[20] Although a number of studies have demonstrated the social and economic impacts of both electricity and water infrastructure, poor tariff and subsidy design can result in the persistence of low quality service.

Tariff reform is a potential tool to increase revenue generation and improve infrastructure provision. Although many acknowledge the necessity of tariff reform in developing countries, attempts to enact price changes are often met by resistance and protest.[21] Such violent responses are particularly concerning where governments are relatively weak or not well-established.[22] Policymakers are left to identify tariff reform that is politically acceptable.

[20]For example, many of the countries in the former Soviet Union had water and electricity infrastructure constructed during the mid-20th century. However, there are many stories from the post-independence period of infrastructure, particularly water infrastructure, for which tariffs were insufficient or non-existent. The infrastructure was not maintained and eventually fell into disrepair, often ceasing to function altogether.

[21]There are a number of examples of protests against increases in tariff rates for both water and electricity services. Arguably the most well-known protest occurred in Cochabamba, Bolivia, in response to increases in water prices in 2000. However, there are many recent examples of protests in response to changes in electricity tariffs. For example, in 2015 there have been major protests in response to electricity tariff increases in both Armenia and Ukraine.

[22]A doubling of electricity prices for all residential consumers in Kyrgyzstan during early 2010 is largely

When raising electricity prices for everyone is not political feasible, shifting the burden of price reform to richer consumers may be more palatable.

Higher income households in Kyrgyzstan have higher electricity consumption (Figure 9). The figure shows the empirical cumulative distributions of daily electricity consumption in winter 2014, split into five income brackets chosen to each contain approximately the same number of households. For the lowest income quintile, more than half of households have electricity consumption that would place them on the first tier of the new IBP. For the highest income quintile, nearly three quarters of households have consumption that would place them on the second tier of the IBP. These households are also much more likely to have extremely high electricity consumption, with a considerable proportion having consumption in excess of 150 kWh per day.[23]

A two-part IBP places a larger burden on the richest households than an uniform tariff that raises the same revenue (Figure 10). For each of the five income brackets, we calculated the mean increase in monthly electricity bills as a result of switching from the previous uniform tariff to the new IBP. For this exercise we held electricity consumption constant at its observed level in winter 2014. As expected from their higher electricity consumption, the highest income households faced the largest increase in their bills as a result of the new tariff: a mean increase of US$25 per month. By contrast, the bills for the lowest income households increased by less than $10 per month.

Based on the total revenue that would be raised by the IBP, we calculated the uniform tariff that would raise the same revenue, again assuming that consumption is held constant. The second group of bars in Figure 10 shows the mean increase in monthly electricity bills under this revenue-equivalent uniform tariff. The higher uniform tariff would increase the electricity bills for households in the first two income quintiles. However, the highest income households would have a substantial reduction in their electricity bills compared to the IBP.

This result has important implications for the political acceptability of tariff reforms. As shown in Section 4, many respondents perceived the new tariff as being flatter than the true tariff. As a result, they would underestimate the effect of the price changes on high income households, potentially creating discontent about the perceived distributional effect of the tariff change. In particular, inattentive consumers who know about higher prices on the new tariff, but do not realize that they are not on the high price tier, might have an unreasonably

believed to have contributed to country-wide unrest and the ousting of the president at that time.

[23]Borenstein (2012) studies the redistributional effect of increasing block tariffs in California, using a novel procedure to match electricity consumption to income distribution data from the census. He finds a similar result that most of the redistribution under IBP comes from the households in the top income bracket.

negative perception of the tariff reform. Our results suggest that information programs to inform users about tariff changes should incorporate a personalized component (such as a calculation from the electricity company showing the household's old and new bills) to help consumers understand the effect of a tariff change.

7 Conclusion

Nonlinear price schedules have long been used to balance efficiency and distributional goals. However, consumers may not understand complex tariffs or they may not be attentive to their consumption within a billing period, both of which may reduce the effectiveness of nonlinear pricing. The costs and benefits of both learning about the tariff structure and understanding one's location on the price schedule will differ across consumers. As a result, it may not be optimal for all consumers to do so.

We developed a novel price elicitation instrument to directly measure perceptions of a new electricity tariff that was introduced in Kyrgyzstan in December 2014. Through the instrument, we can measure both respondents' knowledge of the price schedule and attention to consumption. We show considerable heterogeneity in tariff knowledge, even among the households that were aware of the recent tariff reform. Households with the highest level of tariff understanding reduced their electricity consumption by the largest amount. However, using our measure of attention to electricity consumption, we find the reduction in electricity consumption to be driven by the inattentive respondents who do not know where their consumption places them on the tariff schedule.

Our analysis highlights the role of heterogeneous consumer response to complex pricing structures. Informing and educating consumers about the calculation of their utility bills under new price structures is valuable and could potentially improve the political and financial feasibility of nonlinear pricing. When people understand how they work, a carefully designed nonlinear tariff can be effective in reducing consumption and increasing revenue in a politically acceptable way.

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Figure 1: Electricity tariffs in Kyrgyzstan

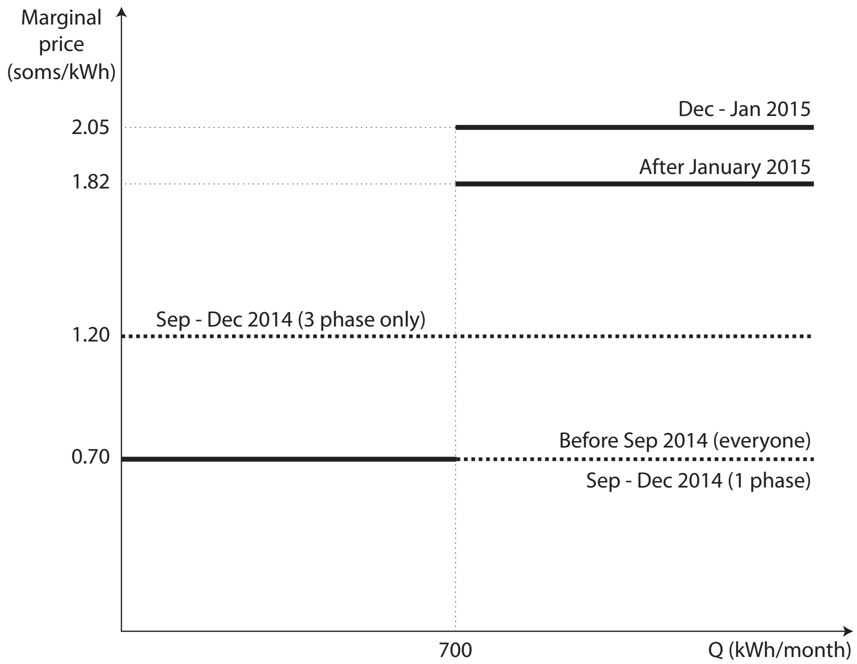


Figure 2: Calculation of marginal prices from reported bill schedule

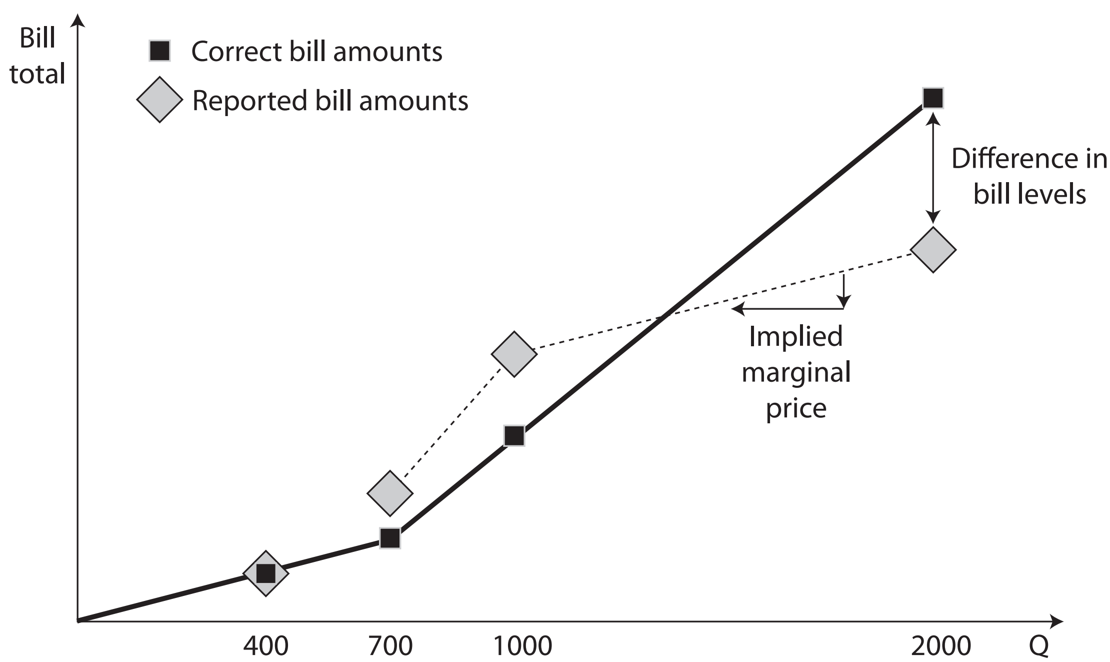
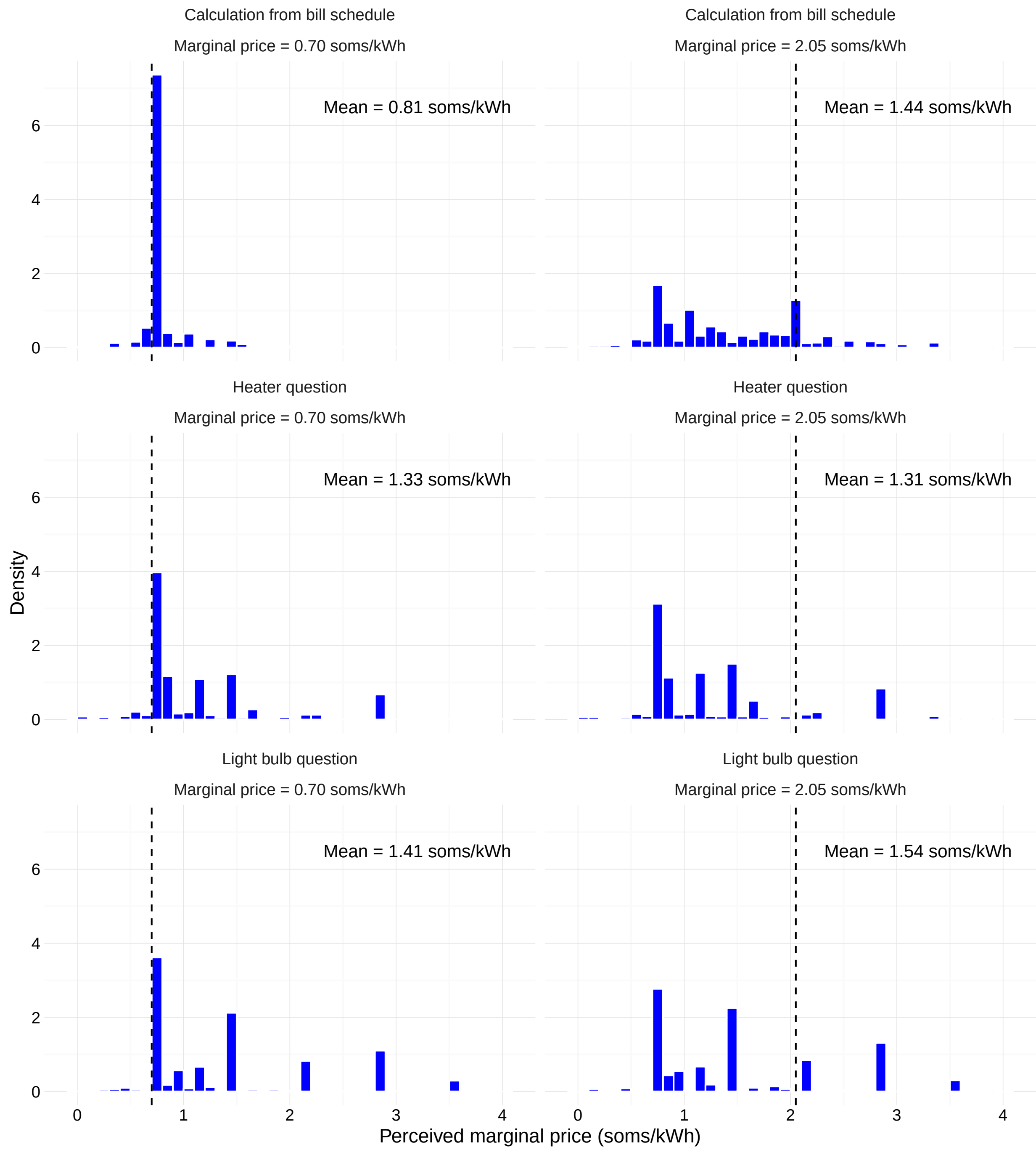
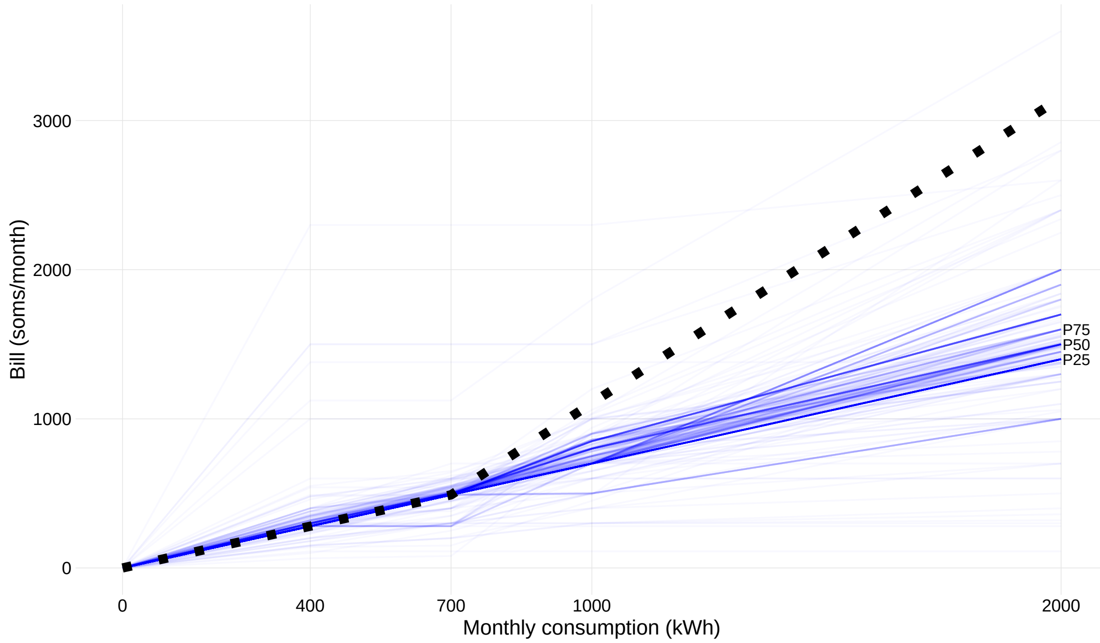


Figure 3: Distribution of perceived marginal prices, by question and true marginal price



Note: The top row shows the implied marginal price calculated from the four points on the tariff schedule reported by respondents. The middle and bottom rows show the results from the direct elicitation of marginal price, framed using heating and lighting costs respectively. The dashed vertical lines show the true marginal price faced by the respondents in January 2015.

Figure 4: Distribution of bill responses for lowest tariff knowledge group



Note: Dotted line shows the true price schedule. Other lines on the graph show individual responses for each respondent classified in the low tariff knowledge group based on their implied marginal prices. Quantiles on the bill reports at 2000 kWh are shown on the right of the graph.

Figure 5: Distribution of bill responses for middle tariff knowledge group

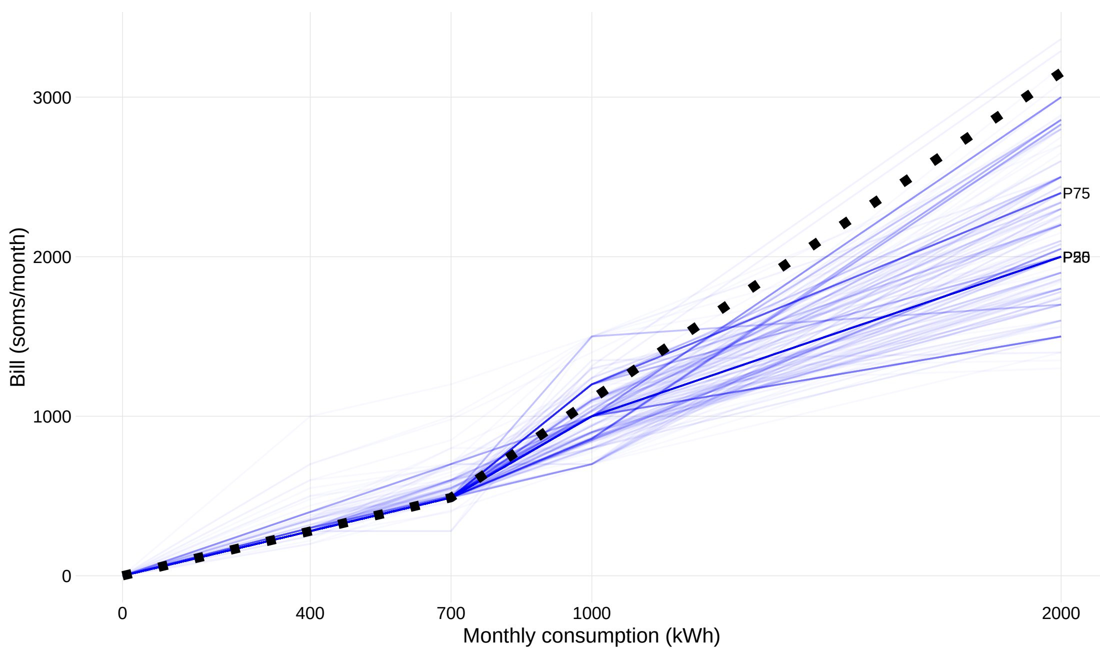


Figure 6: Distribution of bill responses for high tariff knowledge group

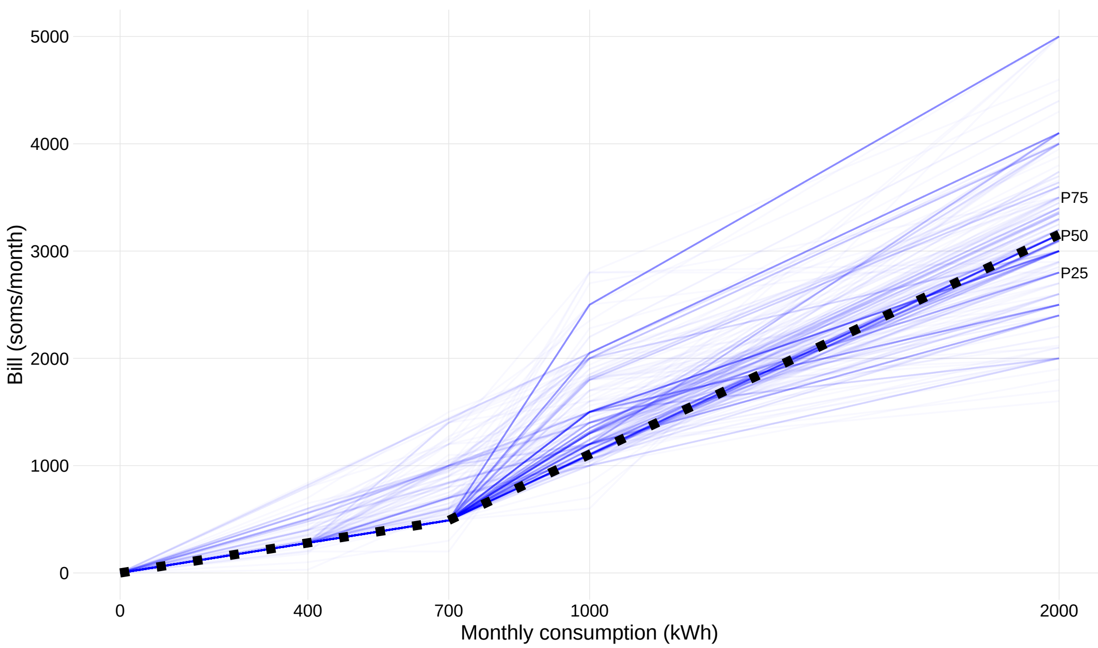


Figure 7: Clustering assignment of observations to tariff knowledge groups using K-means (K=2)

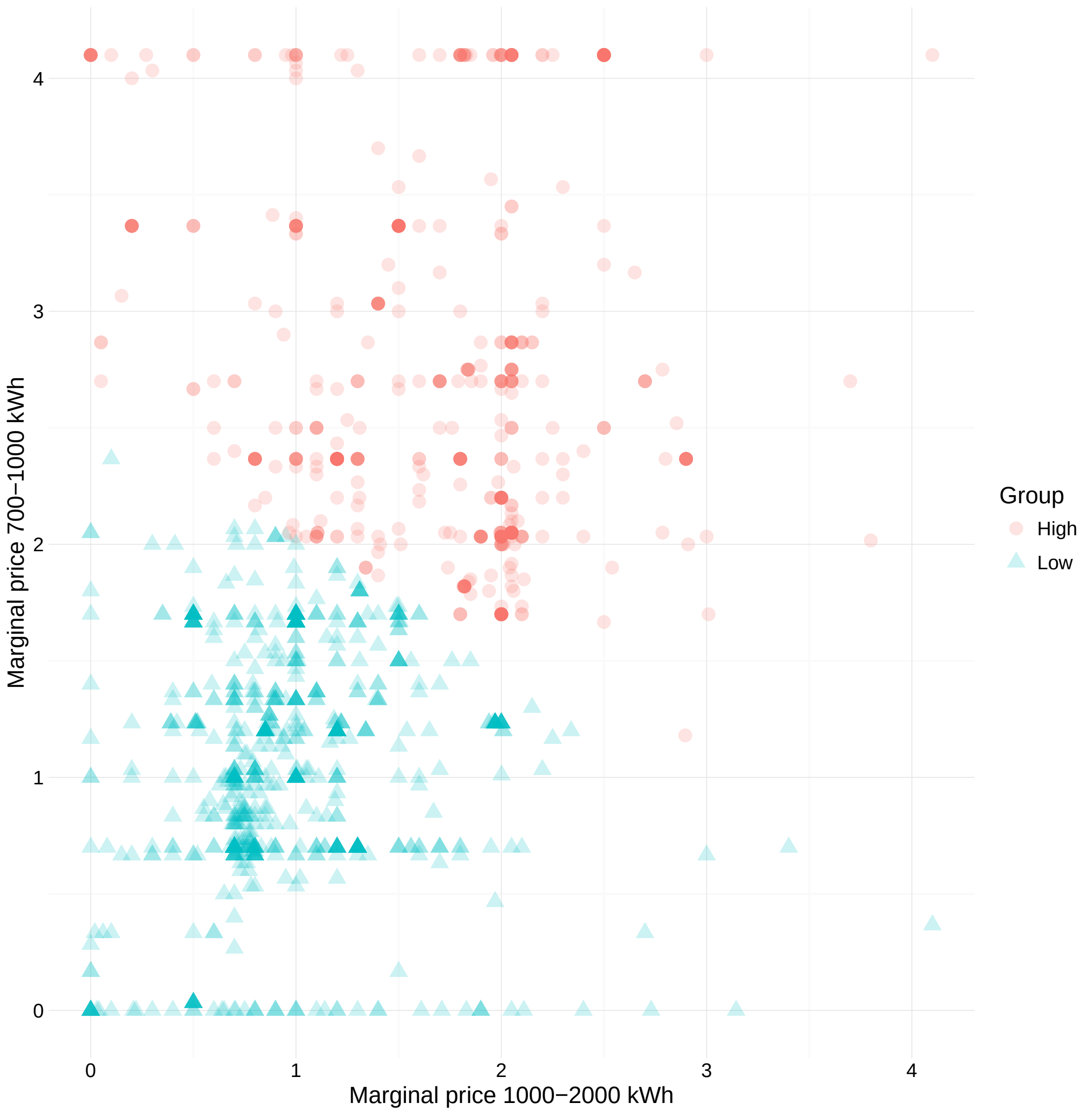
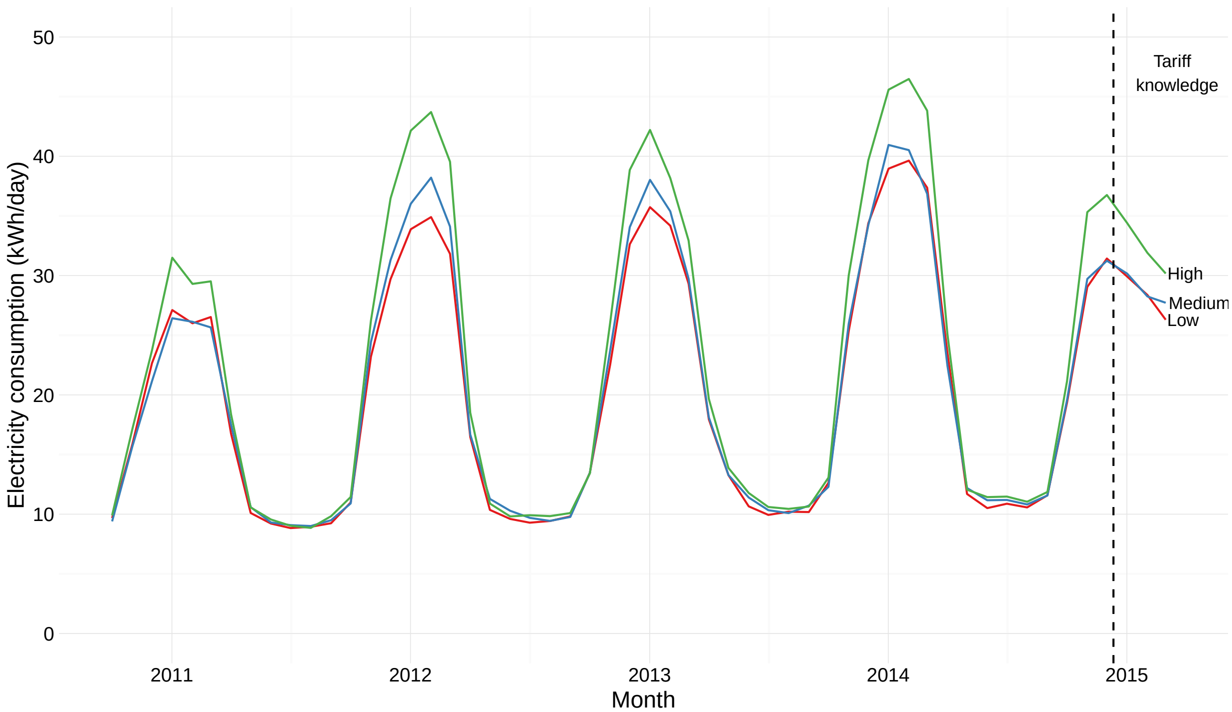
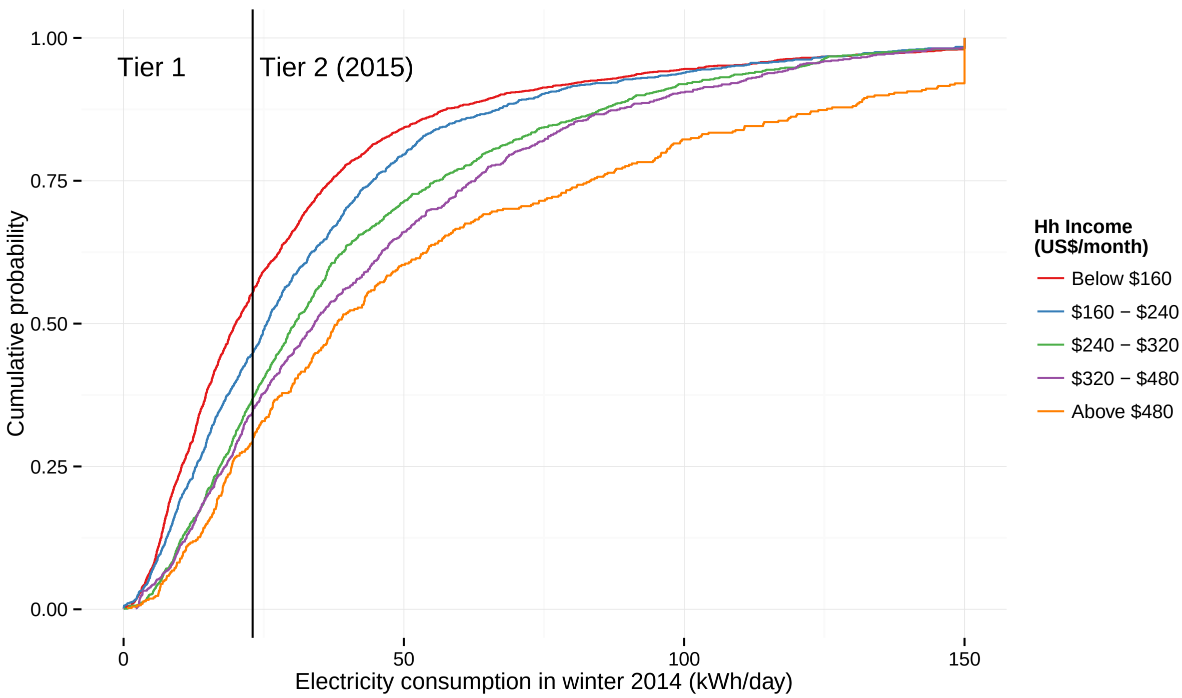


Figure 8: Mean daily electricity consumption, 2010–2015, by tariff knowledge group



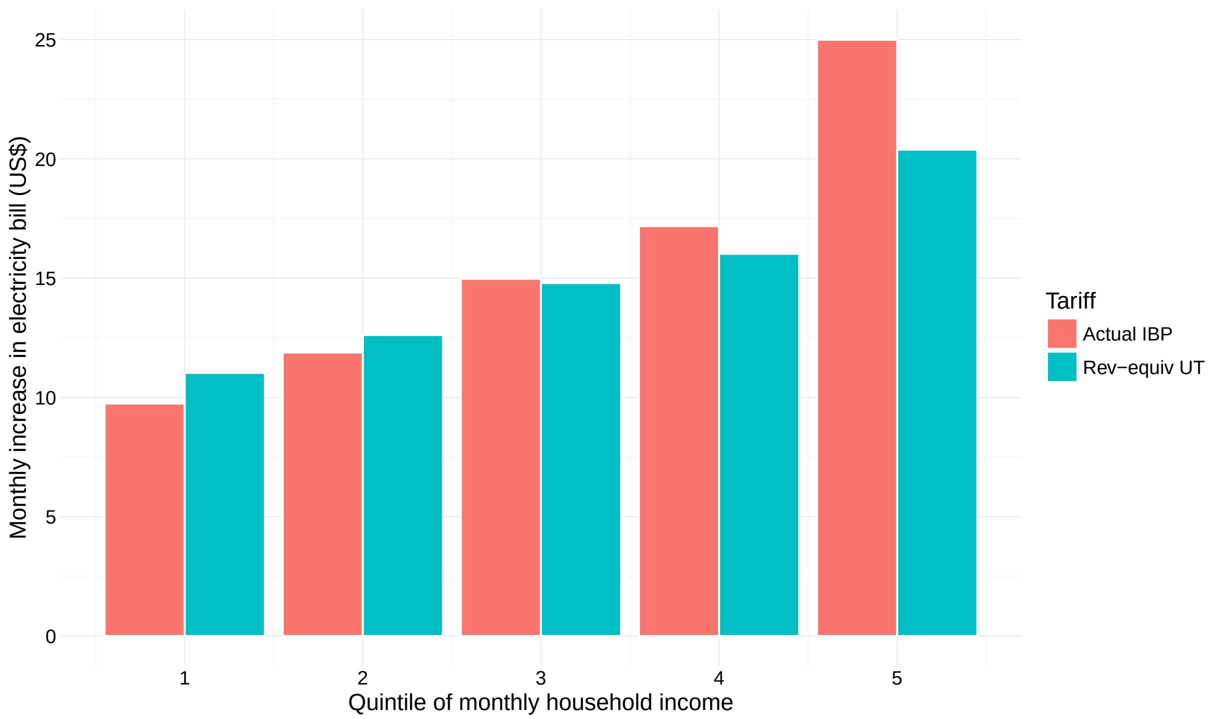
Note: The graph shows the mean consumption for households in the three tariff knowledge categories. Only households with at least four years of non-zero monthly consumption are included.

Figure 9: Cumulative distribution of daily electricity consumption, winter 2014, by income category



Note: The graph shows the empirical cumulative distribution of daily electricity consumption, for each of five income brackets. The vertical line shows the maximum quantity that can be consumed at the Tier 1 price under the 2015 tariff.

Figure 10: Mean increase in electricity bill by tariff structure and household income



Note: The left bars show the mean increase in monthly electricity bills switching from the uniform tariff to the IBT, holding consumption constant at the 2014 level. The right bars show the mean increase in bills switching to a hypothetical uniform tariff that raises the same revenue as the IBT, holding consumption constant.

Table 1: Survey and price elicitation responses

	N	% of total	Electricity use (kWh/day)	
			Winter 2014	Winter 2015
Full sample	2688	100.0%	39.1	30.2
Reasons for survey non-response				
Address not found	266	9.9%	38.1	31.7
Unable to access building	243	9.0%	42.7	31.7
No response	149	5.5%	42.6	30.3
Refused interview	121	4.5%	39.4	32.6
Other reason	40	1.5%	35.5	25.1
Total non-responses	819	30.5%	40.3	31.3
Total survey responses	1869	69.5%	38.6	29.7
Price elicitation exercise				
Refused to attempt	88	3.3%	40.5	29.8
Unable to answer	128	4.8%	35.9	28.8
Incomplete answer	158	5.9%	39.8	27.6
Completed bill questions	1495	55.6%	38.6	30.0

Table 2: Summary statistics on tariff knowledge

		Tariff knowledge		Bill report within 10%		
	Obs.	Quantity	Price	700	1000	2000
Overall	1495	67%	37%	77%	36%	19%
2014 winter electricity						
Below 700 kWh/month	621	64%	27%	76%	33%	14%
Above 700 kWh/month	874	69%	44%	77%	37%	22%
Education						
Incomplete secondary	116	62%	35%	72%	36%	15%
Complete secondary	708	65%	34%	75%	36%	16%
Some college	354	70%	38%	82%	34%	21%
Complete 4-year college	313	72%	42%	78%	35%	22%
Village size						
Less than 500 households	183	52%	22%	68%	38%	3%
500 - 1000	360	50%	18%	73%	33%	16%
1000 - 2000	303	71%	57%	80%	45%	31%
More than 2000	649	79%	42%	80%	32%	19%
Household income						
Below US$150/month	413	60%	27%	72%	29%	16%
$150 - $300	502	64%	33%	76%	32%	16%
Above $300	279	66%	37%	81%	33%	21%
Not reported	301	85%	61%	80%	53%	25%
Age						
Under 30 years	230	66%	37%	73%	34%	18%
30 - 60	972	69%	36%	78%	36%	19%
Over 60	292	62%	39%	75%	34%	18%
Sex						
Female	890	70%	37%	78%	35%	19%
Male	605	63%	36%	75%	37%	19%

Notes: The "tariff knowledge" columns show the proportion of households who correctly answered the quantity question and the price question on the worksheet. "Bill report within 10%" shows the proportion of households who correctly calculate the total bill under the new tariff, for monthly consumption of 700 kWh, 1000 kWh and 2000 kWh. For this table, a correct answer is defined as being within 10 percent of the true value.

Table 3: Household demand for electricity: base estimation

	Log electricity consumption (kWh/day)				
	(1)	(2)	(3)	(4)	(5)
Log price	0.06***	−0.28***	−0.39***	−0.24***	−0.32***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Log price × mid group				−0.04	−0.08**
				(0.03)	(0.04)
Log price × high group				−0.09***	−0.13***
				(0.03)	(0.03)
Price variable	Marginal	Exp. Marg.	Marginal	Exp. Marg.	Marginal
Instruments	-	-	Exp. Marg.	-	Exp. Marg.
Household × month FE	Y	Y	Y	Y	Y
Temperature controls	Poly	Poly	Poly	Poly	Poly
Time trend	Y	Y	Y	Y	Y
Group × temperature	-	-	-	Y	Y
Group × time trend	-	-	-	Y	Y
Observations	75,362	75,362	75,362	75,362	75,362

Notes: Each observation is the (logged) monthly electricity consumption for a household in kWh/day. Months with zero consumption or with consumption above 300 kWh/day are excluded. Only households with at least four years of positive electricity consumption are included. Expected marginal prices are calculated based on predicted household electricity consumption, using household-specific demand models estimated with data from before the price change. Temperature variables are cubic polynomials in heating and cooling degree days (with a base point of 18 degrees Celsius). Price perception groups are determined based on the implied marginal prices from the four bills questions on the price elicitation instrument. Standard errors are calculated based on Arellano (1987) and are robust to arbitrary within-household serial correlation and cross-household heteroskedasticity.
*p<0.1; **p<0.05; ***p<0.01

Table 4: Household demand for electricity: inattentiveness results

	Log electricity consumption (kWh/day)				
	(1)	(2)	(3)	(4)	(5)
Log price	-0.0003	-0.27^{***}	-0.35^{***}	-0.25^{***}	-0.33^{***}
	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)
Log price × med know				-0.03	-0.03
				(0.04)	(0.04)
Log price × high know				-0.04	-0.03
				(0.04)	(0.04)
Log price × inattent.	0.13^{***}	-0.09^{***}	-0.29^{***}	0.002	-0.02
	(0.03)	(0.03)	(0.04)	(0.05)	(0.05)
Log price × inattent. × med				-0.07	-0.29^{***}
				(0.07)	(0.10)
Log price × inattent. × high				-0.23^{***}	-0.72^{***}
				(0.07)	(0.11)
Price variable	Marginal	Exp. Marg.	Marginal	Exp. Marg.	Marginal
Instruments	-	-	Exp. Marg.	-	Exp. Marg.
Household × month FE	Y	Y	Y	Y	Y
Temperature controls	Poly	Poly	Poly	Poly	Poly
Time trend	Y	Y	Y	Y	Y
Group × temperature	-	-	-	Y	Y
Group × time trend	-	-	-	Y	Y
Observations	64,672	64,672	64,672	64,672	64,672

Notes: Inattentiveness is equal to 1 if both answers to the marginal price questions on the price elicitation instrument were inconsistent with the respondent's price tier in January 2015. If either answer is consistent then inattentiveness is equal to 0. Group interactions include full interactions with both the inattentiveness and tariff knowledge variables. There are fewer observations than in Table 3 because not all respondents completed the marginal price questions. See also notes to Table 3.

*p<0.1; **p<0.05; ***p<0.01

Table 5: Demand results for alternative methods of classifying households

	Log electricity consumption (kWh/day)				
	(1)	(2)	(3)	(4)	(5)
Log price	−0.36***	−0.32***	−0.32***	−0.24***	−0.29***
	(0.04)	(0.02)	(0.03)	(0.03)	(0.03)
Log price × med know	−0.001		−0.03	−0.05	−0.08*
	(0.05)		(0.04)	(0.05)	(0.05)
Log price × high know	0.03	−0.07**	−0.02	−0.07	−0.07
	(0.05)	(0.03)	(0.04)	(0.04)	(0.04)
Log price × inattent.	−0.03	−0.23***	−0.05	−0.17***	−0.06
	(0.06)	(0.05)	(0.05)	(0.05)	(0.05)
Log price × inattent. × med	−0.23***		−0.28***	−0.24***	0.01
	(0.09)		(0.10)	(0.08)	(0.07)
Log price × inattent. × high	−0.84***	−0.23**	−0.72***	−0.37***	−0.22***
	(0.15)	(0.09)	(0.11)	(0.08)	(0.07)
Knowledge classification	Tariff quiz	k-Means	Tariff sched.	Tariff sched.	Tariff sched.
Attentiveness classification	MP tier	MP tier	Pred. tier	Pred. all	Bill recall
Price variable	Marginal	Marginal	Marginal	Marginal	Marginal
Instruments	Exp. Marg.	Exp. Marg.	Exp. Marg.	Exp. Marg.	Exp. Marg.
Household × month FE	Y	Y	Y	Y	Y
Temperature controls	Poly	Poly	Poly	Poly	Poly
Time trend	Y	Y	Y	Y	Y
Group × temperature	Y	Y	Y	Y	Y
Group × time trend	Y	Y	Y	Y	Y
Observations	64,672	64,672	64,672	64,672	74,615

Notes: Column 1 replicates Column 5 from Table 3. Column 2 defines two price perception groups (of unequal size) using the K-means algorithm applied to the marginal price variables. Column 3 divides the sample based on the number of correct answers to the multiple choice questions on price and quantity. Column 4 uses the respondent education ("mid group" has some college and "high group" has a four-year college degree). See also notes to Table 3.
*p<0.1; **p<0.05; ***p<0.01

Table 6: Additional robustness checks for household demand model

	Log electricity consumption (kWh/day)				
	(1)	(2)	(3)	(4)	(5)
Log price	-0.26^{***}	-0.10^{***}	-0.27^{***}	-0.19^{**}	0.02
	(0.03)	(0.03)	(0.03)	(0.08)	(0.03)
Log price × med know	−0.06	−0.04	−0.07	0.05	−0.02
	(0.05)	(0.04)	(0.05)	(0.13)	(0.04)
Log price × high know	-0.08^{*}	0.05	−0.06	−0.08	−0.03
	(0.05)	(0.04)	(0.04)	(0.11)	(0.04)
Log price × inattent.	−0.002	-0.15^{***}	−0.02	0.19	0.01
	(0.06)	(0.05)	(0.05)	(0.14)	(0.05)
Log price × inattent. × med	-0.29^{***}	-0.21^{**}	-0.29^{***}	−0.31	-0.15^{*}
	(0.10)	(0.10)	(0.10)	(0.22)	(0.08)
Log price × inattent. × high	-0.81^{***}	-0.45^{***}	-0.78^{***}	−0.19	−0.05
	(0.11)	(0.10)	(0.11)	(0.21)	(0.07)
Price variable	Marginal	Marginal	Marginal	Marginal	Placebo
Instruments	Exp. Marg.	Exp. Marg.	Exp. Marg.	-	Exp. Marg.
Household × month FE	Y	Y	Y	Y	Y
Temperature controls	Bins	Poly	Poly	Poly	Poly
Time control	Trend	-	Year	Trend	Trend
Group × temperature	Y	Y	Y	Y	Y
Group × time control	Y	-	Y	Y	Y
Observations	64,672	64,672	64,672	59,846	50,183

Notes: Column 1 uses the proportion of days with mean temperature within 5 degree Celsius bins. Column 2 replaces the group time trend with group-specific year variables (where the years are defined from April to March). Column 3 includes a dummy variable for the households facing the 3-phase tariff in late 2014, interacted with the group variables. Column 4 estimates the model using data before December 2014, when the only price variation was the higher (uniform) 3-phase tariff. Column 5 shows results for a placebo test using only data before April 2014, but with the price variables shifted back by one year. See also notes to Table 3.
$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table 7: Energy efficiency upgrades and price knowledge

	Dep. var × 100				
	Insulation	Window insul.	CFLs	New fridge	Upgraded?
	(1)	(2)	(3)	(4)	(5)
Mid group (0/1)	2.20	9.74**	1.98	5.09	−1.36
	(2.33)	(3.81)	(3.23)	(3.67)	(2.24)
High group (0/1)	5.73**	17.68***	8.31***	8.57**	3.61
	(2.43)	(3.91)	(3.21)	(3.54)	(2.36)
Monthly expenditure	0.38***	−0.15	0.31	0.23	0.04
	(0.14)	(0.23)	(0.28)	(0.21)	(0.18)
Winter 2014 kWh/day	0.06***	0.00	0.06	0.01	0.06***
	(0.02)	(0.04)	(0.04)	(0.04)	(0.02)
No. of rooms	1.77***	1.50	6.28***	−0.55	1.78***
	(0.68)	(1.10)	(1.00)	(0.96)	(0.68)
Hh members	0.64	2.54***	−0.71	2.94***	0.42
	(0.58)	(0.78)	(0.73)	(0.71)	(0.54)
Own house	7.22	11.54***	12.80***	−2.92	0.03
	(5.33)	(4.08)	(4.93)	(3.71)	(3.02)
Apartment	−3.37	−7.05	−7.18	1.57	−3.32
	(3.38)	(5.07)	(5.07)	(3.65)	(3.93)
Village size (000 hh)	1.10***	2.30***	0.58	−0.21	−1.09**
	(0.35)	(0.68)	(0.58)	(0.59)	(0.45)
Mean of dep. var.	11.0	65.3	25.7	30.1	10.9
Observations	1,393	1,393	1,393	1,393	1,393

Notes: The table shows marginal effects from a logit model for each measure of energy efficiency investments. For readability all results are multiplied by 100. Excluded group for the price knowledge variables is "Low group". The variables measure whether the house has any type of insulation, plastic windows or wooden windows with plastic film, any energy efficient light bulbs, or a fridge newer than five years old. "Upgraded?" means the household reported making an upgrade to their house as a result of the electricity price change. Standard errors are computed from 250 clustered bootstrap replications, where the cluster is the transformer (the primary sampling unit).

Appendix: Price elicitation instrument

Survey Number: ______________

Below are the electricity bills for 4 different families for January 2014 and January 2015.

Calculate the approximate amount of the bills in January 2015.

Family 1

электро

January 2014

Consumption: **400 kWh**

Total bill: **280** soms

электро

January 2015

Consumption: **400 kWh**

Total bill: [   ] soms

Family 2

электро

January 2014

Consumption: **700 kWh**

Total bill: **490** soms

электро

January 2015

Consumption: **700 kWh**

Total bill: [   ] soms

Family 3

электро

January 2014

Consumption: **1000 kWh**

Total bill: **700** soms

электро

January 2015

Consumption: **1000 kWh**

Total bill: soms

Family 4

электро

January 2014

Consumption: **2000 kWh**

Total bill: **1400** soms

электро

January 2015

Consumption: **2000 kWh**

Total bill: soms

Now think about how the new tariffs have affected the cost of using electrical appliances in your home.

Approximate if necessary.

The use of this light bulb for 4 more hours each day would increase the bill by:

5 soms in January 2014.

[ ] soms in January 2015.

The use of this heater for 4 more hours each day would increase the bill by:

12**5** soms in January 2014.

[ ] soms in January 2015.

How much electricity can be used without paying a higher amount?

- ☐ 300 kWh
- ☐ 500 kWh
- ☐ 700 kWh
- ☐ 1000 kWh
- ☐ I do not know

What is the price for 1 kWh after exceeding this quantity, in January 2015?

- ☐ 0.7 soms
- ☐ 1.2 soms
- ☐ 1.5 soms
- ☐ 2.05 soms
- ☐ I do not know