Price Perceptions and Electricity Demand with Nonlinear Tariffs

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Outline of the talk

Nonlinear (increasing block) prices are used for electricity and water rates in many countries

- Set low marginal price for a basic level of consumption
  - Provides access to "lifeline" quantity for poor households
- Set high marginal price for consumption in excess of that amount
  - Provides a conservation incentive for the high users
- Since usage is typically higher for richer households, a larger share of system costs are recovered from those households most able to pay
- Potentially improves the political acceptability of tariff reforms

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- Since usage is typically higher for richer households, a larger share of system costs are recovered from those households most able to pay
- Potentially improves the political acceptability of tariff reforms
- Many of these benefits depend on consumers understanding the price schedule

Determining the optimal response to nonlinear prices can be costly for consumers

- Two components to the perceived marginal price for additional consumption with a nonlinear tariff
  - Knowledge of the tariff schedule
  - Attentiveness to own consumption: where does the household lie on the tariff schedule?

Determining the optimal response to nonlinear prices can be costly for consumers

- Two components to the perceived marginal price for additional consumption with a nonlinear tariff
  - Knowledge of the tariff schedule
  - Attentiveness to own consumption: where does the household lie on the tariff schedule?
- We develop a price elicitation instrument to directly measure these components of price perception
  - Tariff knowledge: respondent estimates bill amounts at different quantities along the price schedule
  - Attentiveness: respondent estimates marginal price of consuming additional service (providing information on perceived pricing tier)

We applied our price elicitation instrument soon after the introduction of a new nonlinear tariff

- Kyrgyzstan reformed electricity tariffs in December 2014
  - Uniform tariff replaced by an increasing block price (IBP)
  - Price above 700 kWh/month increased to nearly 3$\times$ previous level
- In conjunction with our own household energy survey, we applied a price elicitation instrument to directly measure understanding of the new tariff and attentiveness to consumption
- We combine these price perceptions with administrative billing data to study how consumption responses depend on components of the perceived price

Main finding: tariff knowledge matters... but especially for inattentive households

- Households with the best tariff knowledge were more responsive to the new tariff
- Splitting results by attentiveness, we find that tariff knowledge has the largest effect for inattentive respondents
  - These are people who do not know where their consumption places them on the new tariff
- Consumers who know about the new tariff, but do not realize this has little effect on them, have the largest consumption response

Results are consistent with coverage of the electricity price changes in the local media

КирТАГ

КЫРГЫЗСКОЕ ТЕЛЕГРАФНОЕ АГЕНТСТВО

Many people try to save electricity, but sometimes this leads to undesirable results, as in the case of Cholpon-Ata resident Gulnara Dosov, who is the mother of two children.

"I make money from preparing cakes to sell at the market. We are saving, trying not to bring our power consumption to 700 kWh. While the oven is on, the heaters were turned off, but it was still cold. As a result, the children were sick all winter and the younger child is still coughing."

February 19, 2015

Several previous studies have suggested that consumers are inattentive to complex electricity price schedules

- Our results are closely related to experimental work by Kahn and Wolak (2013)
  - They find that providing low tier consumers with information about their position on the tariff schedule leads to an increase in their electricity consumption
- Other work (Shin (1985), Borenstein (1989), Ito(2014)) shows that consumers respond to the average price not the marginal price
  - Perceived price in these papers is not broken down into knowledge and attentiveness components

Our methodological approach complements the existing literature on nonlinear price perceptions

- We develop independent measures of the components of price perceptions and use these to compare consumption outcomes
- This means we can explore heterogeneity in perceptions across different types of consumers
- We also collect detailed survey data about household characteristics and energy use, so we can incorporate other characteristics (apart from price perception) that affect electricity use
- Little previous work on price perceptions in developing countries—where utility bills are more salient and price changes often much larger

Outline of the talk

Kyrgyzstan is a low-income country in Central Asia with a continental climate

Electricity infrastructure constructed during the Soviet Union and has deteriorated since

- Nearly 100 percent of households are connected to the grid
- 90 percent of generation is hydroelectric

Price reform is urgently needed but politically challenging

- Residential electricity prices are low: 1.2 U.S. cents per kWh
- Prices have remained fixed in nominal terms since 2008
  - Except a temporary doubling of price in early 2010, which contributed to violent protests and overthrow of government
- Low electricity prices lead to inefficient use of electricity
  - Households are increasingly heating with electricity
  - Low levels of investment in infrastructure persist
- Government choice between rolling blackouts and expensive imported electricity

Tariff reform was introduced in December 2014

- September 2014: 70% price increase just for houses with 3-phase connections (large consumers)
  - This was challenged in the courts
- Two-tier increasing block price schedule then introduced for all residential consumers
  - First tier: consumption below 700 kWh charged 1.2 US cents per kWh (same as existing price)
  - Second tier: consumption above 700 kWh charged 3.5 US cents per kWh
- Announced November 25 and took effect December 11

We combine administrative records with our own data collected in northern Kyrgyzstan

- Complete household-level electricity records for one district
  - Include 40,000+ consumers from a mix of urban areas and smaller villages
  - Identify location, meter type, transformer, etc
  - Provide monthly electricity consumption data from late 2010 to the present
- Daily weather data for nearby weather stations
- Household energy survey data (March-April 2015)
  - Demographics, housing and appliance characteristics, energy-consumption practices
  - Included price perception instrument to measure understanding of new electricity tariff

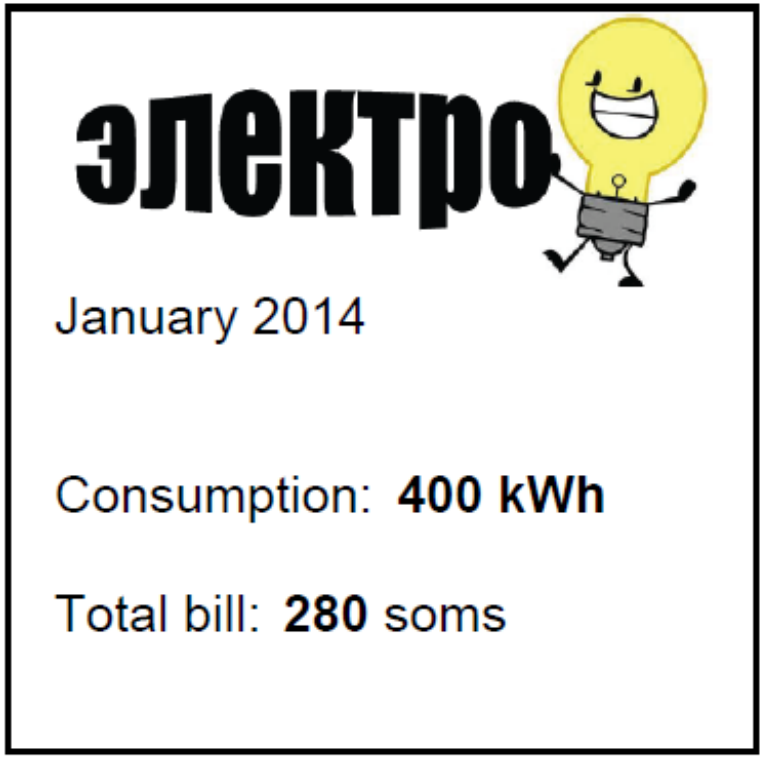
Outline of the talk

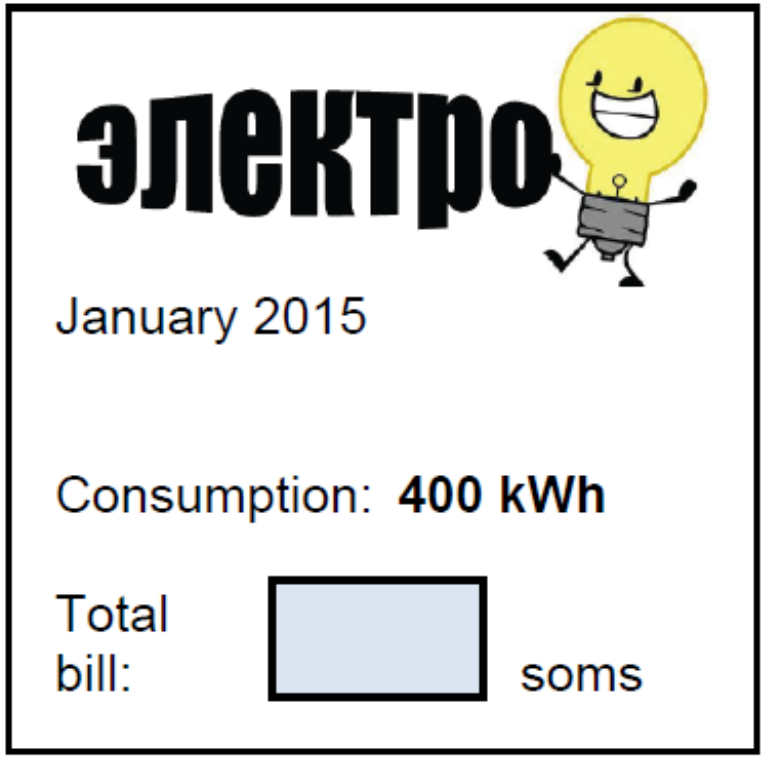
Price elicitation instrument allows us to decompose components of the perceived price

- Short worksheet that respondents completed on their own with limited surveyor interaction
  - Note that numeracy and literacy rates are relatively high in our setting
- Questions analyzed different components of the perceived marginal price
  1. **Knowledge** of the new tariff schedule
  2. **Attentiveness** to own consumption and where it lies on the price schedule

Four questions about the total bill amount at different consumption quantities test knowledge of price schedule

Family 1





Two questions measure the respondent's attentiveness to their consumption

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

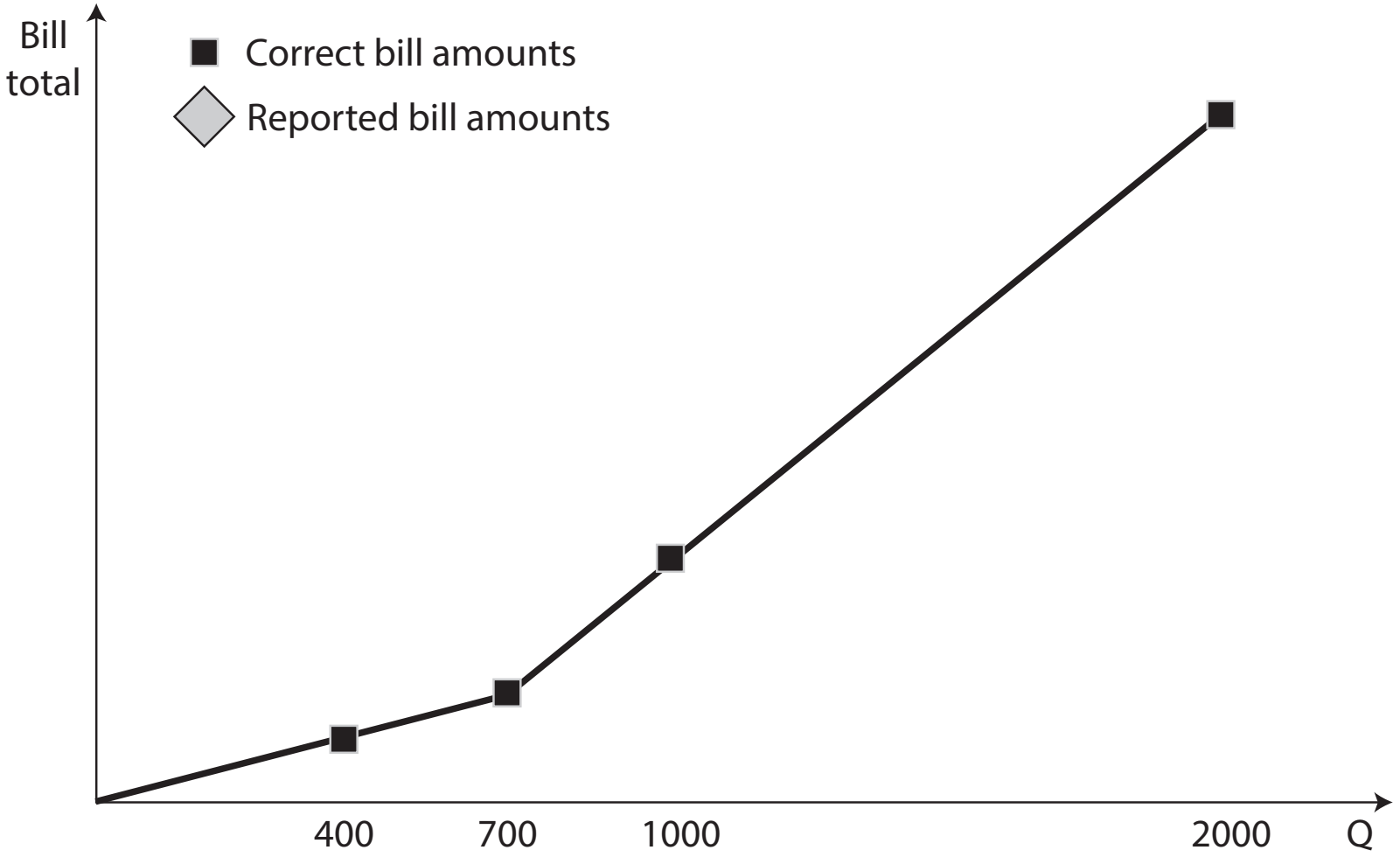
Approximate if necessary.

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

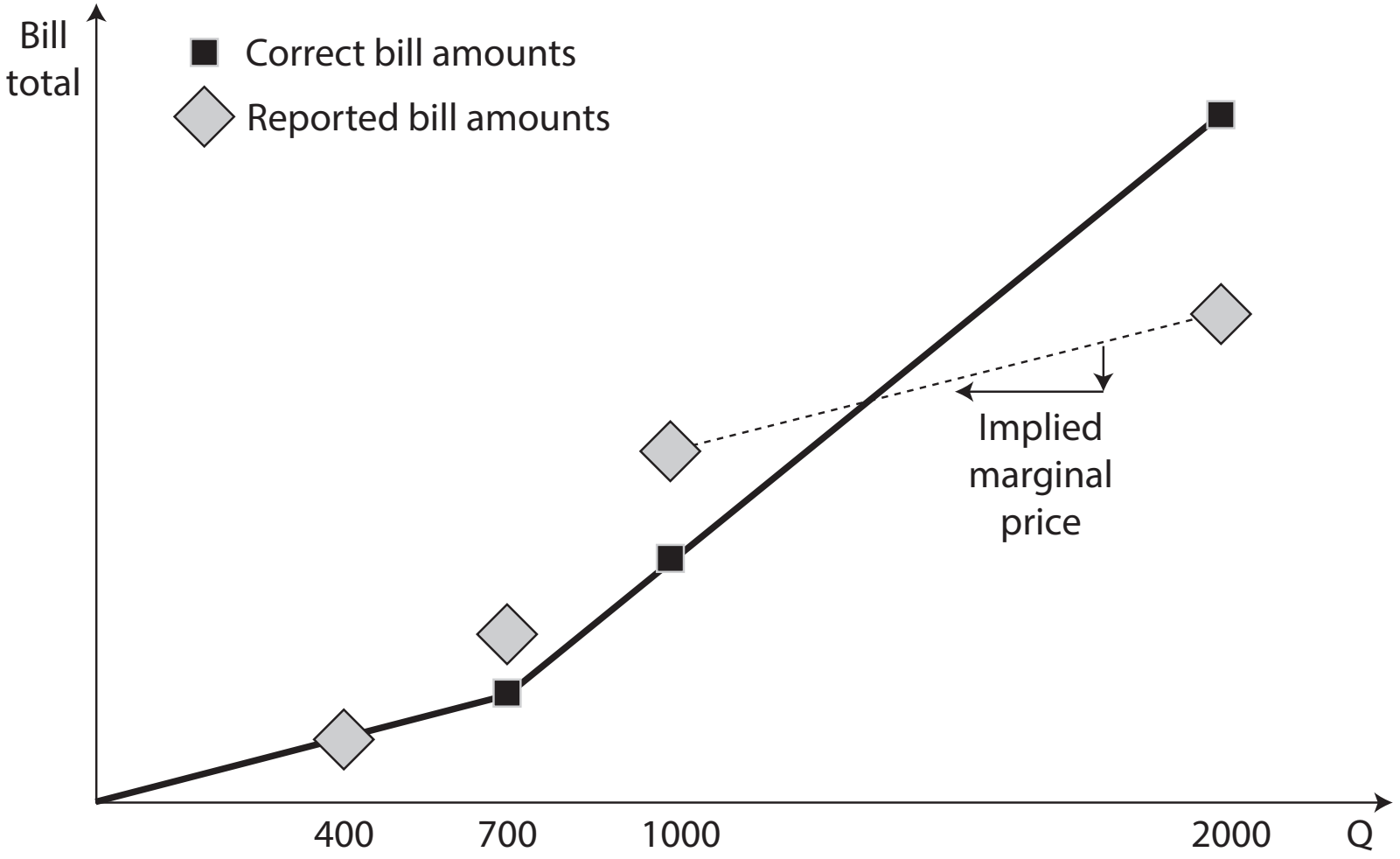
5 soms in January 2014.

☐ soms in January 2015.

Construct tariff knowledge index using responses to the four bill total questions



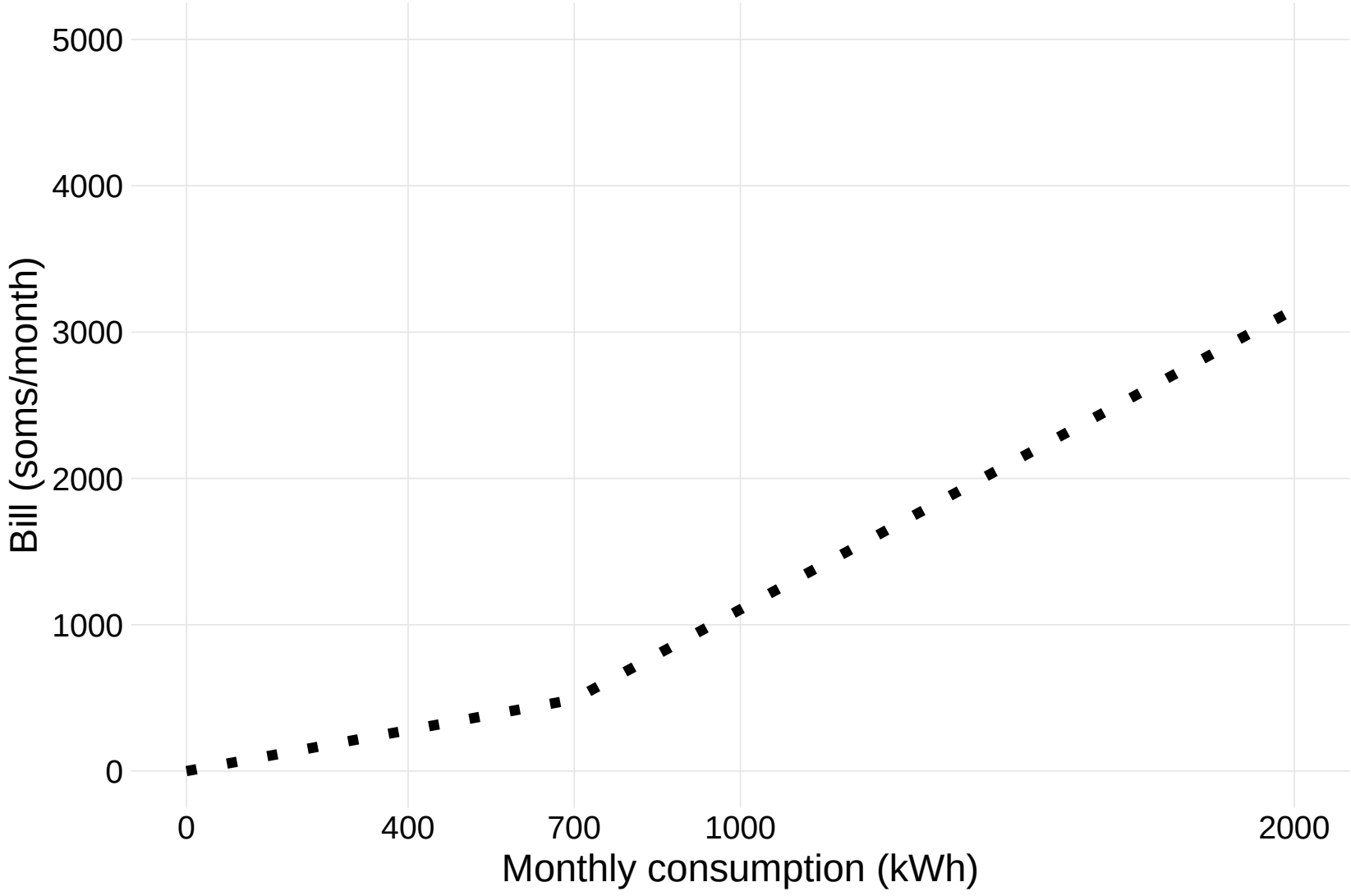
Construct tariff knowledge index using responses to the four bill total questions



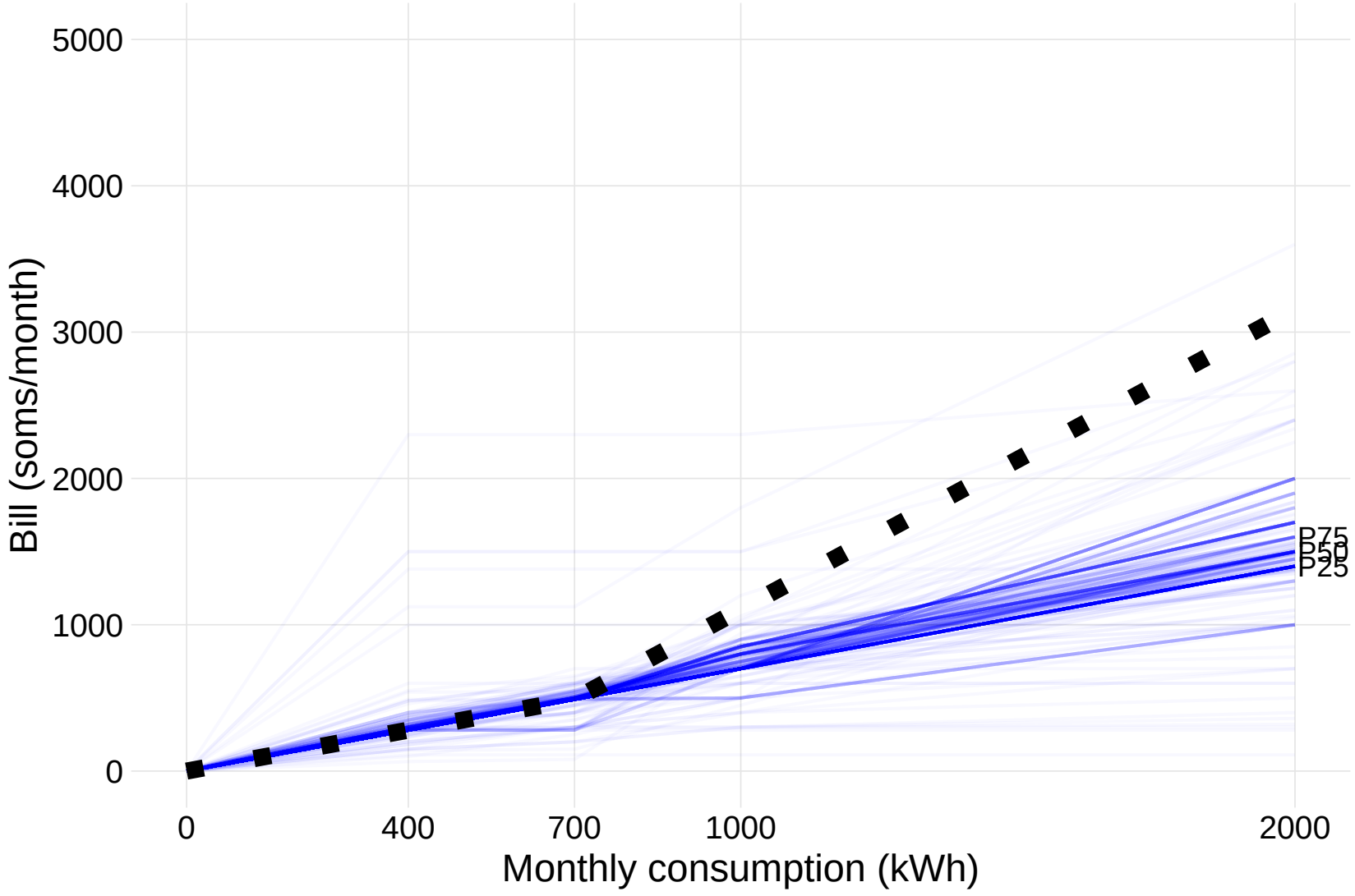
Construct tariff knowledge index using responses to the four bill total questions

- On three consumption segments, calculate the percent difference between the implied marginal price and the true marginal price
  1. 400 - 700 kWh
  2. 700 - 1000 kWh
  3. 1000 - 2000 kWh
- Calculate average difference for these three segments
- Rank respondents by this average difference and divide sample into terciles: "low", "medium", "high" tariff knowledge

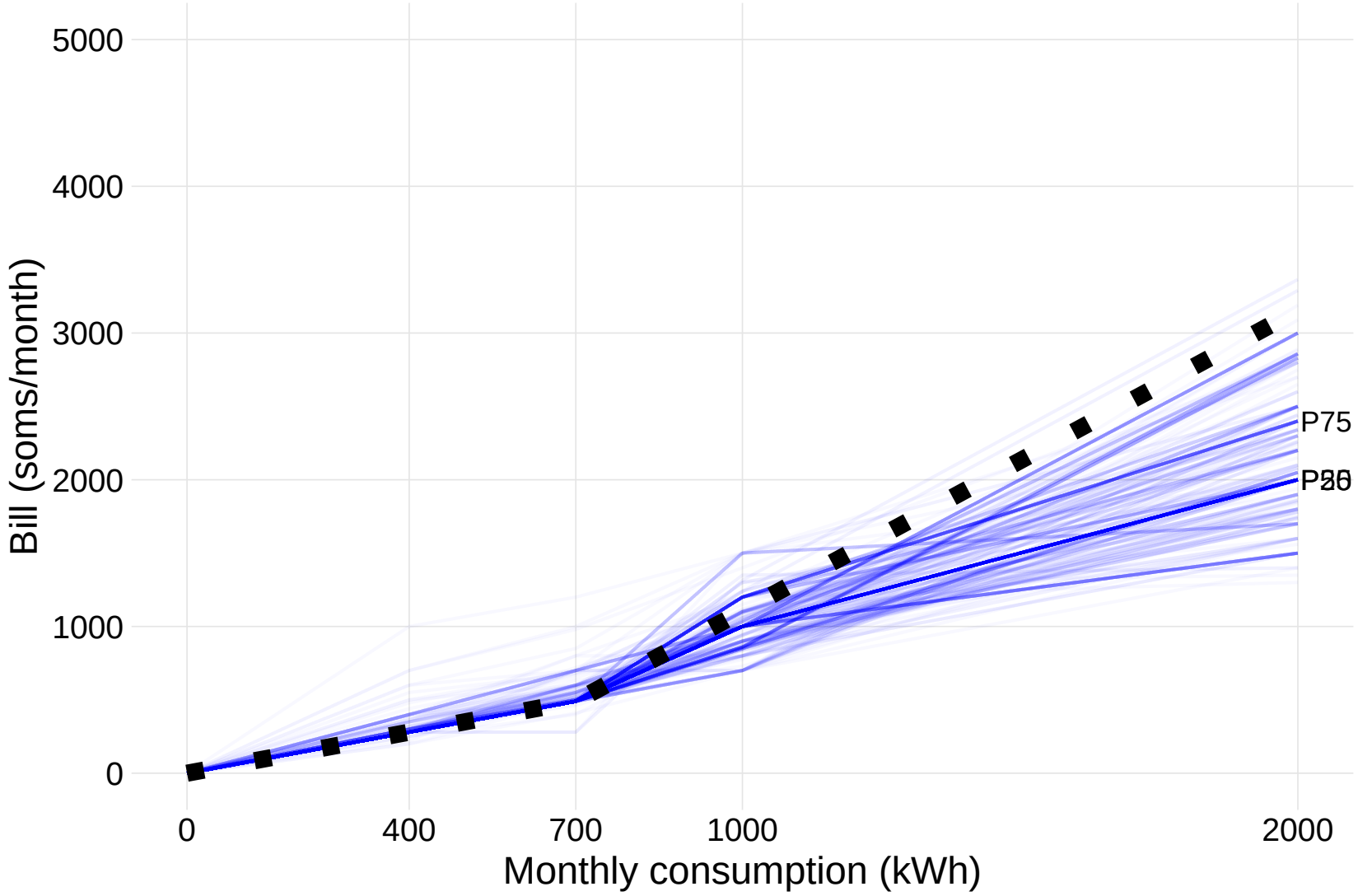
Examine the reported tariff schedule for respondents in the three tariff knowledge groups...



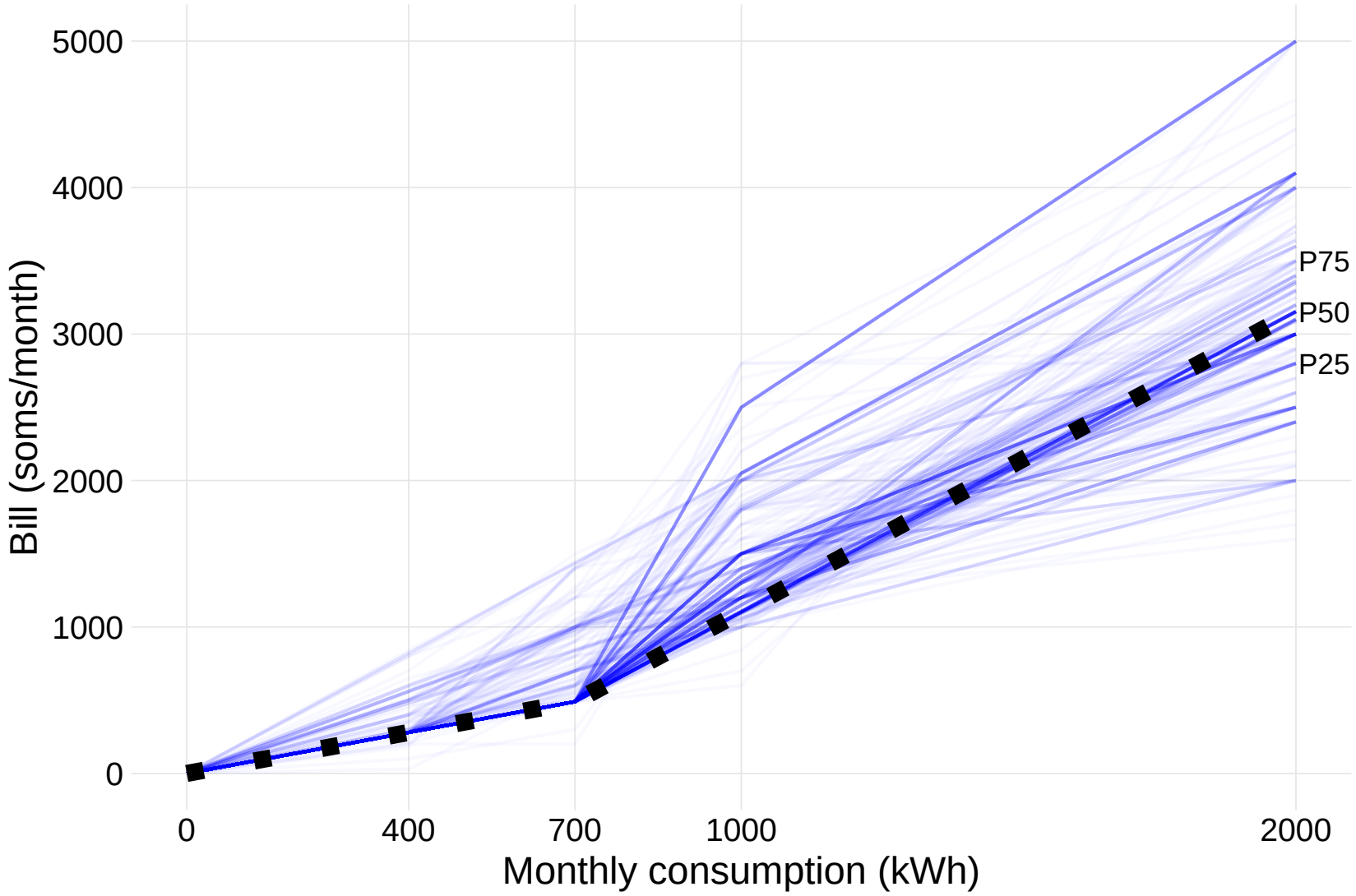
Reported tariff schedule of respondents in the lowest comprehension group



Reported tariff schedule of respondents in the middle comprehension group



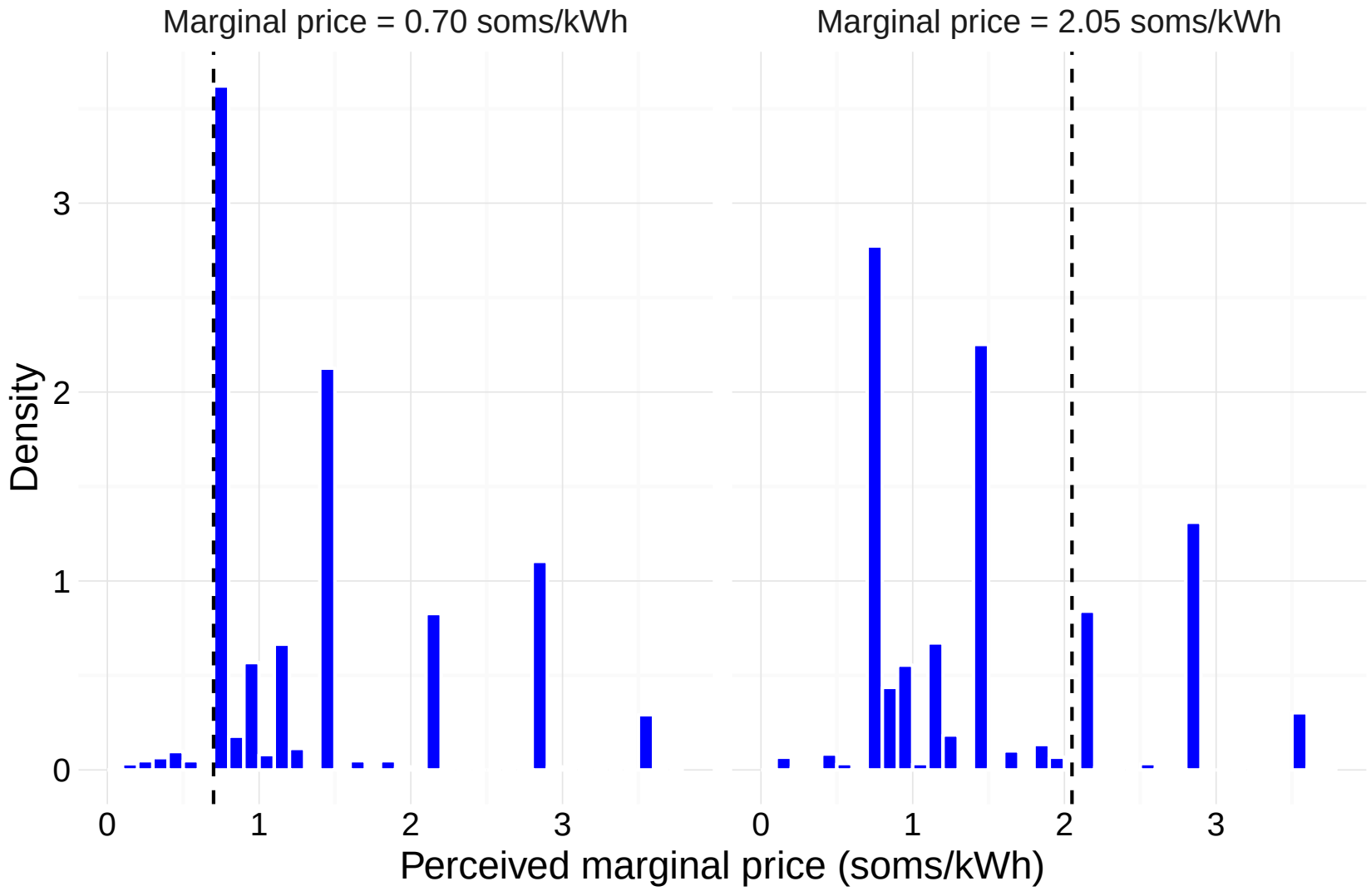
Reported tariff schedule of respondents in the high comprehension group



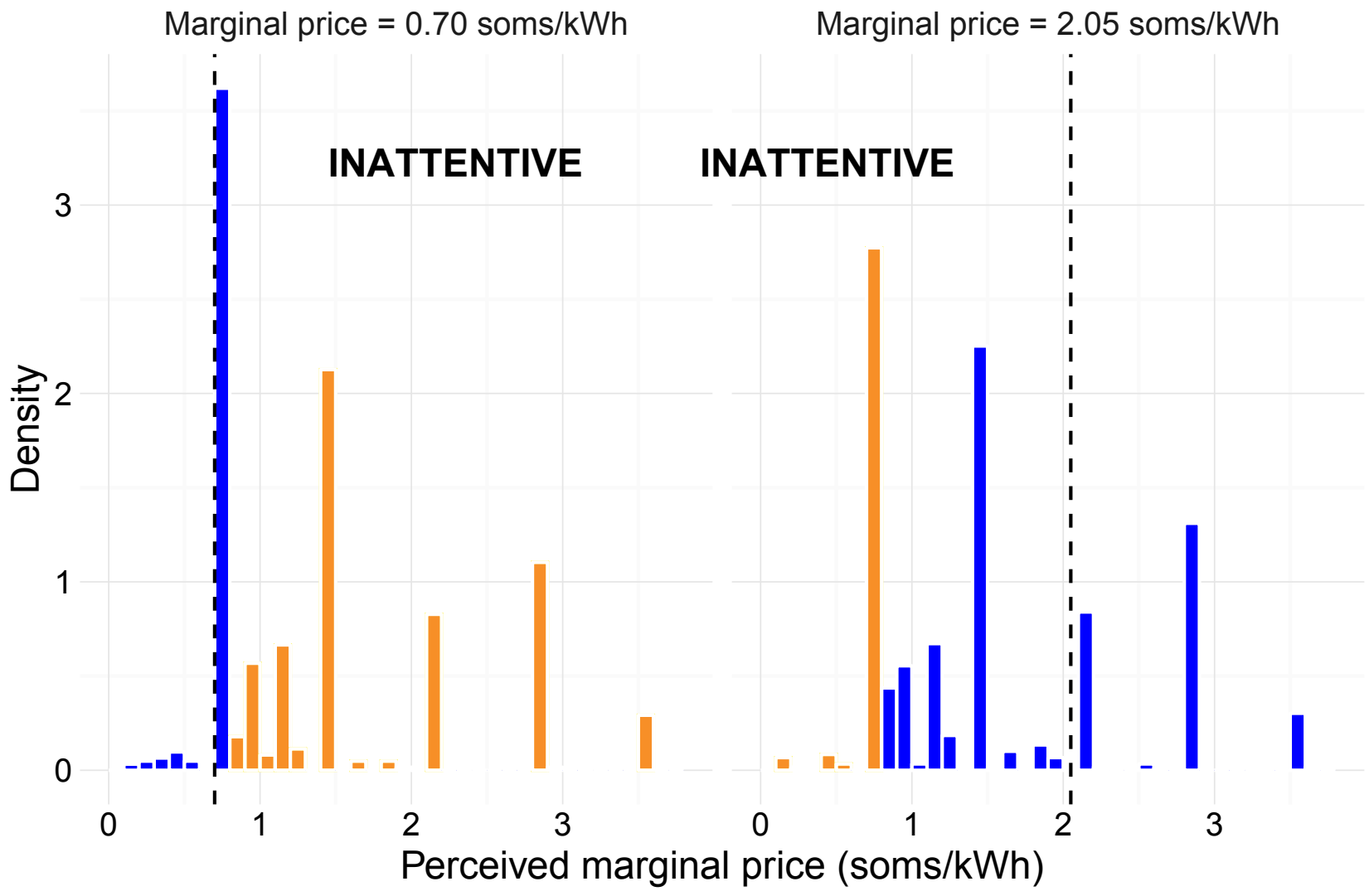
Use responses to attentiveness questions to a measure

- Need to separate computational/knowledge errors from attentiveness to consumption
- Define a binary measure based on whether or not respondents reported facing a higher marginal price than in 2014
  - Attentive to consumption = answer this question correctly based on true change in marginal price
  - Inattentive to consumption = answer this question incorrectly

Implied marginal prices from the question about the cost of lighting consumption



Division of marginal price responses into attentive and inattentive categories

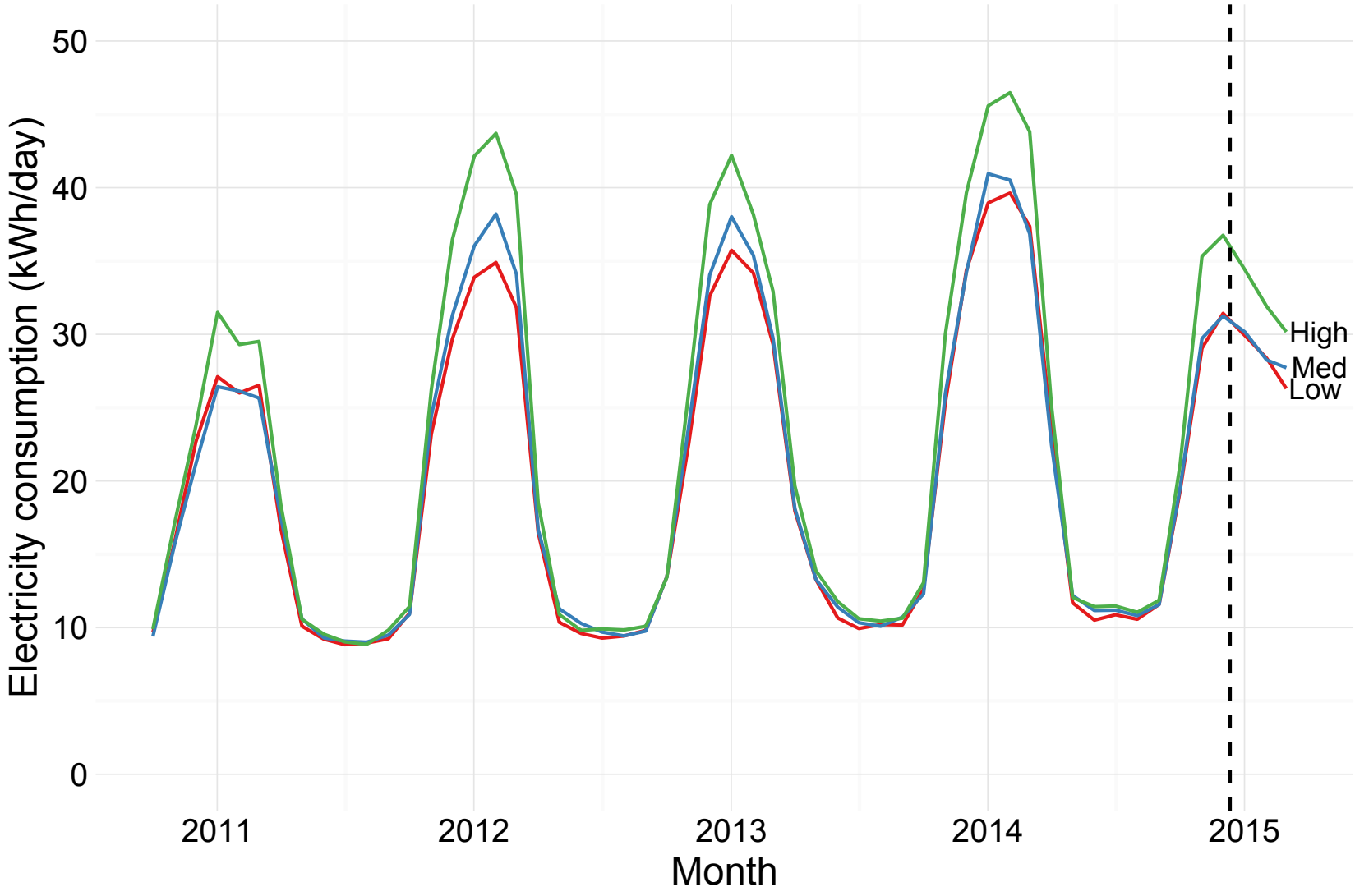


Use responses to marginal price questions to construct attentiveness measure

- Need to separate computational/knowledge errors from attentiveness to consumption
- Define a binary measure based on whether or not respondents reported facing a higher marginal price than in 2014
  - Attentive to consumption = answer this question correctly based on true change in marginal price
  - Inattentive to consumption = answer this question incorrectly
- Two marginal price questions based on lighting and heating energy services
  - Answering either of these correctly $\implies$ attentive
  - Alternative measure for robustness: answer both correctly to be considered attentive

Outline of the talk

Large drop in electricity consumption after introduction of new tariff... but partly due to milder winter



Estimate model of household demand for electricity

- Demand for electricity of household i in month t is given by:

$$\ln q_{it} = \alpha_{im} + \beta_g \ln p_{it} + f(H_t; \delta_g) + \tau_g t + \varepsilon_{it}$$

- Use household-month fixed effects
- Two alternative methods for controlling for temperature (H_t)
  1. Proportion of days lying within discrete temperature bins
  2. Cubic polynomials in heating and cooling degree days
- Allow all effects to vary by the knowledge (and attentiveness) groups g
- Interested in differences in β_g for the different groups

How to overcome dependence of marginal price p_{it} on the consumption quantity q_{it}?

- Instrument for actual price using the expected marginal price (c.f. Mansur and Olmstead, 2011)
  - Price was constant for most of the sample period
  - Use this pre-period to estimate household-specific model of electricity consumption without prices
  - Then predict consumption (and marginal price) in the period with non-linear pricing
- In earlier version: also estimated discrete-continuous model of electricity demand (results were consistent for both methods)

Price elasticity was largest for households in highest price knowledge group

	(1)	(2)	(3)
Log Price	0.06***	-0.24***	-0.32***
	(0.01)	(0.02)	(0.02)
Log Price × Med		-0.04	-0.08**
		(0.03)	(0.04)
Log Price × High		-0.09***	-0.13***
		(0.03)	(0.03)
Price var	Actual MP	Expected MP	Actual MP
Method	OLS	OLS	IV
Household-month FE	Y	Y	Y
Time controls	Trend	Trend	Trend
Temperature	Bins	Bins	Bins

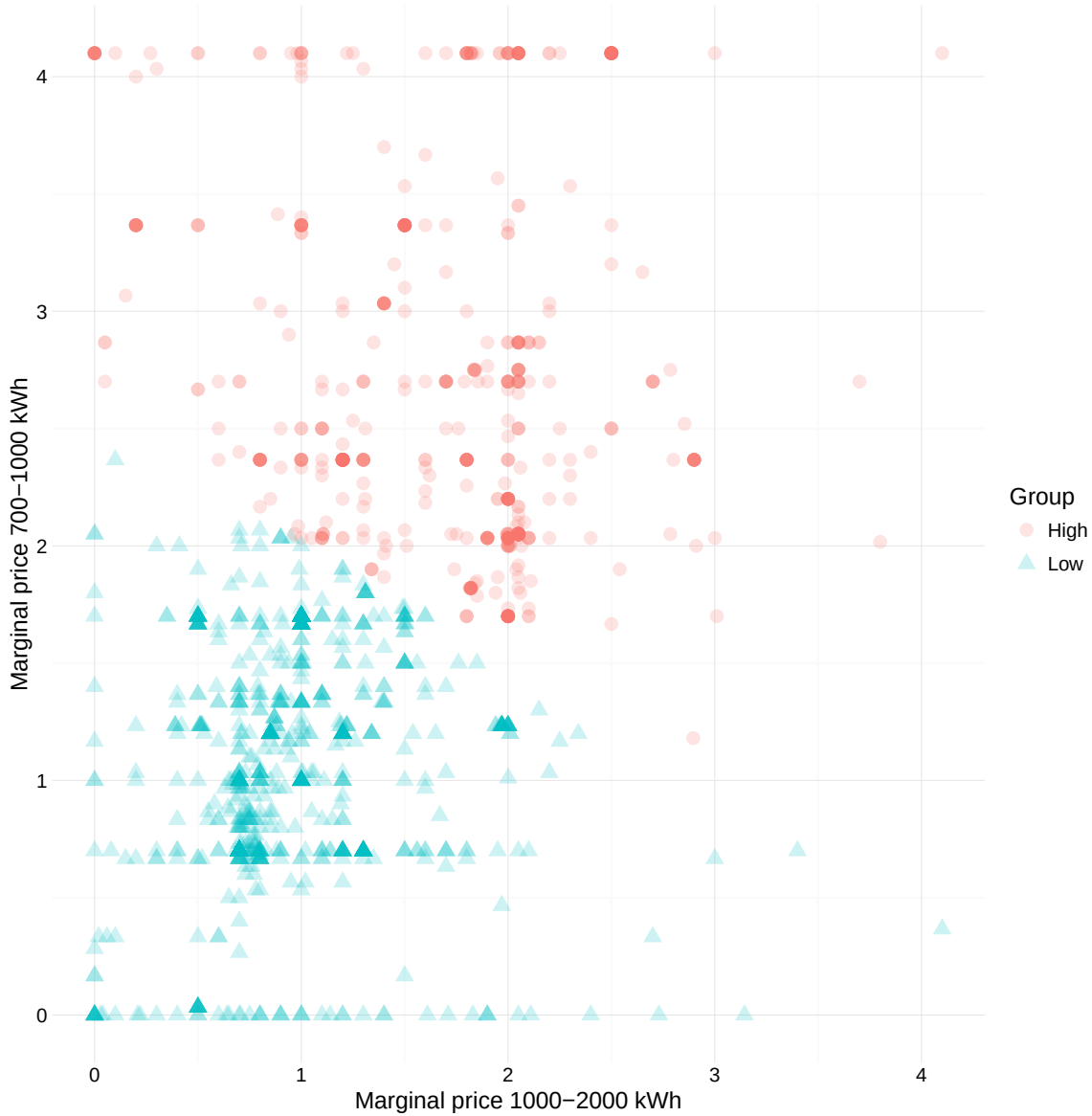
Inattentive households (who know the tariff) are much more responsive to marginal price

	IV	EMP	IV
Log Price	-0.32***	-0.25***	-0.33***
	(0.01)	(0.03)	(0.03)
× Med	-0.08**	-0.03	-0.03
	(0.04)	(0.04)	(0.04)
× High	-0.13***	-0.04	-0.03
	(0.03)	(0.04)	(0.04)
× Inatt.		0.002	-0.02
		(0.05)	(0.05)
× Med × Inatt.		-0.07	-0.29***
		(0.07)	(0.10)
× High × Inatt.		-0.23***	-0.72***
		(0.07)	(0.11)

Alternative knowledge measure: cluster-based analysis of implied marginal prices from bill report questions

- Clustering algorithms (unsupervised learning) look for patterns in the data
- K-means algorithm requires number of clusters K to be predetermined
  - Pick K arbitrary centroids in the data
  - Assign each observation to the nearest centroid
  - Recalculate centroids for each cluster
  - Iterate until centroids do not change
- For this application we use $K = 2$: partition the sample into low and high "comprehension" groups (of unequal size) based on implied marginal prices

Large group of "low knowledge" clustered around old marginal prices; smaller group of "high knowledge"



Alternative knowledge measure: correct multiple choice answers

- Third price knowledge measure: use number of correct answers to the two multiple choice questions
  - No correct answers = low knowledge
  - 1 correct answer = medium knowledge
  - 2 correct answers = high knowledge

Results are robust to alternative definitions of the tariff knowledge groups

	Orig	Cluster	Quiz
Log Price	-0.33***	-0.32***	-0.36***
	(0.04)	(0.02)	(0.04)
× Med	-0.03		-0.001
	(0.04)		(0.05)
× High	-0.03	-0.07***	0.03
	(0.04)	(0.03)	(0.05)
× Inatt.	-0.02	-0.23***	-0.03
	(0.05)	(0.05)	(0.06)
× Med × Inatt.	-0.29***		-0.23***
	(0.10)		(0.09)
× High × Inatt.	-0.72***	-0.23***	-0.84***
	(0.11)	(0.09)	(0.15)

Also develop alternative measures of inattentiveness

- What is the price tier of the household?
  - Base definition: use actual consumption in January 2015
  - Alternative definition: use predicted consumption in January 2015 from household-specific model (data before September 2014)
- Either/both of the marginal price questions answered correctly?
- Did the respondent recall their electricity bill for January 2015?
  - Split sample based on percentage difference between actual bill and reported bills
  - Inattentive = group with worst bill recall

Results are robust to alternative definitions of the inattentiveness measure

	Orig	Pred. all	Bill
Log Price	-0.33***	-0.24***	-0.29***
	(0.04)	(0.03)	(0.03)
× Med	-0.03	-0.05	-0.08*
	(0.04)	(0.05)	(0.05)
× High	-0.03	-0.07	-0.07
	(0.04)	(0.04)	(0.04)
× Inatt.	-0.02	-0.17***	-0.06
	(0.05)	(0.05)	(0.05)
× Med × Inatt.	-0.29***	-0.24***	0.01
	(0.10)	(0.08)	(0.07)
× High × Inatt.	-0.72***	-0.37***	-0.22***
	(0.11)	(0.08)	(0.07)

Results are robust to variety of other specification checks

- Results are robust to alternative specifications of the regression model
  - No time trend
  - Replace time trend with year and month dummies
  - Temperature bins / polynomial in degree days
- Estimate using data before the December 2014 price change
  - No statistically significant results for interaction terms: suggests that differences are due to perceptions of nonlinear tariff
- Run placebo model for price change occurring in December 2013 instead of December 2014

Where did the additional decrease in consumption for inattentive "high knowledge" households come from?

- Previous studies on pricing and information in electricity often found that consumption effects were short-lived
- We can use other information collected in our household energy use survey to provide suggestive evidence on the sources of the change in consumption

High knowledge households were more likely to have a warm house...

- Survey enumerators measured temperatures inside the dwelling
- High knowledge households had the warmest dwellings
- Mean temperature of 19.4 degrees Celsius, compared to 18.5 and 19.3 degrees for the other low and medium groups

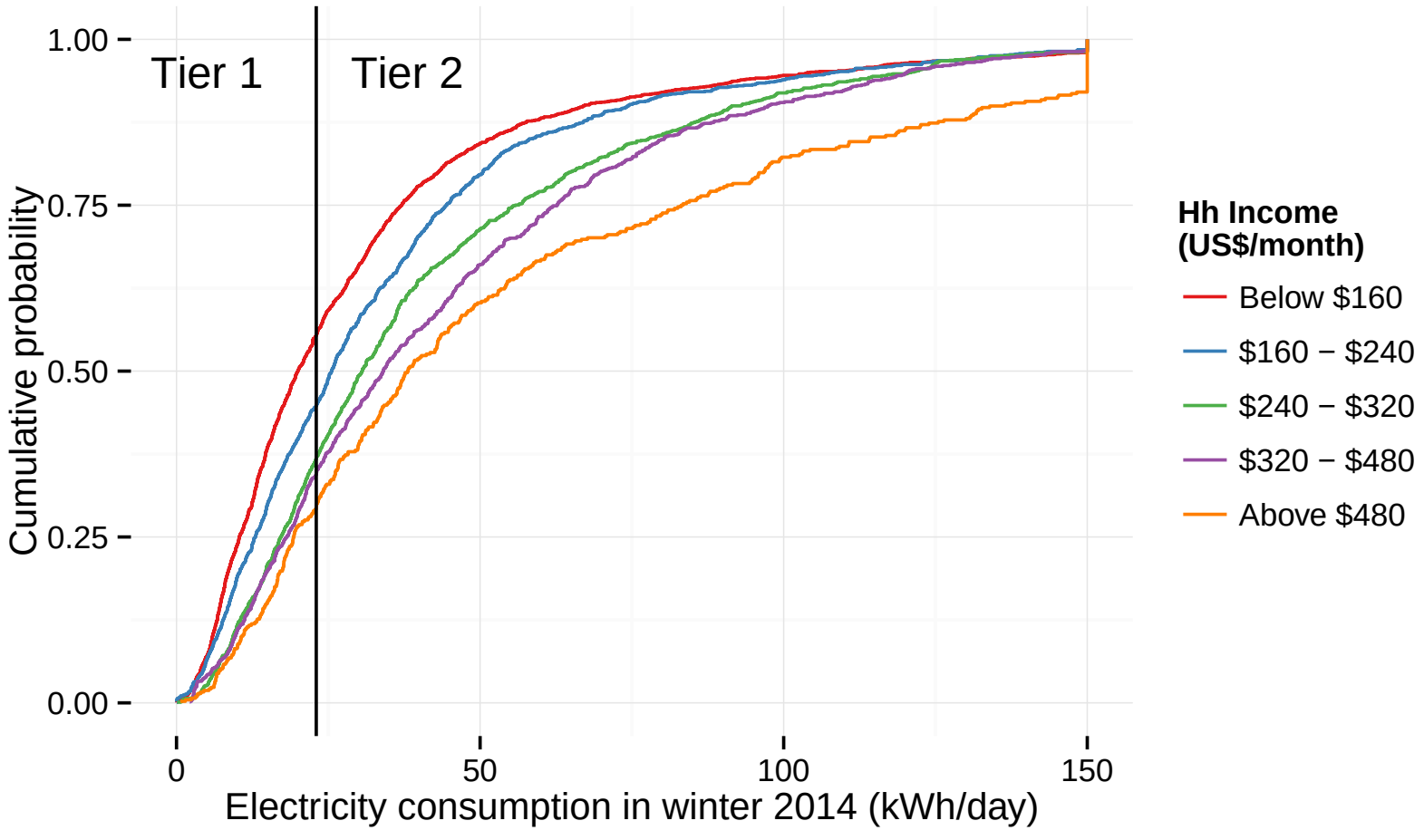
High knowledge households much more likely to have made energy efficiency improvements to their dwellings

	Insul.	Windows	CFLs	Upgrade?
Med know.	2.20	9.74**	1.98	-1.36
	(2.33)	(3.81)	(3.23)	(2.24)
High know.	5.73**	17.68***	8.31***	3.61
	(2.43)	(3.91)	(3.21)	(2.36)
Mean dep. var	11.0	65.3	25.7	10.9
N	1393	1393	1393	1393

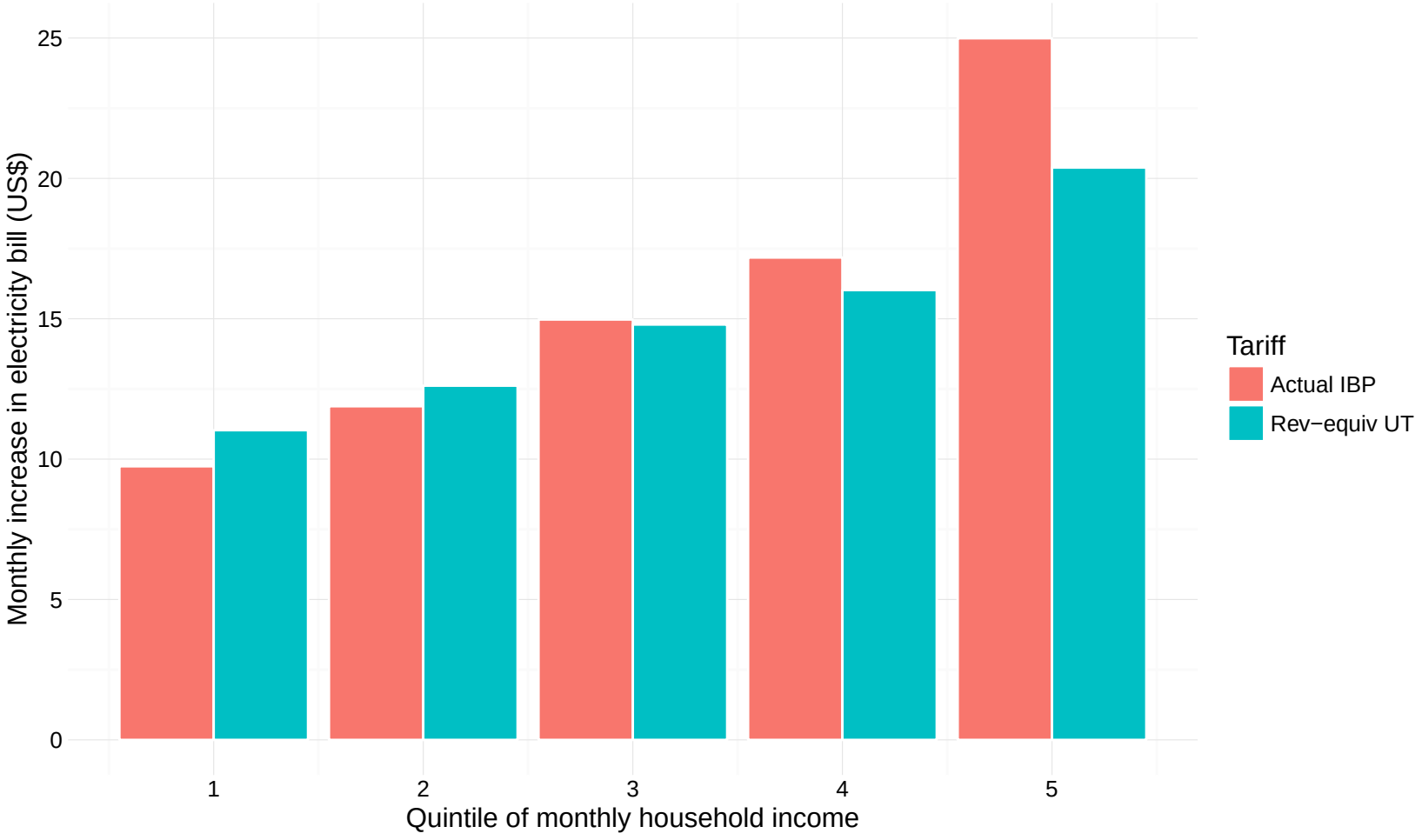
Table shows marginal effects ($\times$100) from a logit regression for each investment measure. Controls for expenditure, electricity use, house and family size, house type and ownership also included.

Outline of the talk

More than half of the lowest income households have consumption below 700 kWh/month



Increasing block pricing has a greater effect on richest households than a revenue-equivalent uniform tariff



Misperceptions of the new tariffs could lead to misunderstandings about its distributional effect

- Potential advantage of IBP: larger effect on richer households
- Misperceptions about the price schedule could affect the political acceptability of the tariff reforms
- Inattentive consumers who know about the higher prices, but do not realize they are not on the high tier, might have negative perception of tariff reforms

Outline of the talk

Conclusion

- Our price elicitation instrument revealed considerable heterogeneity in how well households understand the nonlinear tariff
  - Substantial number understand exactly how bills are calculated with the new tariff
- Differences in understanding correlated with large differences in electricity consumption behavior
  - Reduction in consumption was larger for those households who understood the tariff, but not how it would affect them
- Personalized information about tariff reforms might help to improve their political acceptability