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THE EFFECT OF NUDGES ON PRICES AND PRICE SENSITIVITY IN A RETAIL ELECTRICITY MARKET ENVIRONMENT

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INTRODUCTION

There have been lots of field experiments that have discussed and measured the impact of different monetary and informational incentives and how do these incentives encourage better awareness and, consequently, changes in human behavior regarding inefficient energy use. Such incentives are commonly referred to as nudges. The concept of a nudge was popularized in an economic environment by the well-known book of Thaler and Sunstein (2008). There it is described as „any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives". In other words, a nudge is a useful tool to provoke a specific optimal behavior without removing the possibility of different actions, but just by changing the manner choices are presented to subjects. The fact that the implementation of a nudge does not restrict the freedom of choice makes nudges so important – they are moral and easy to access interventions that are generally designed to increase social welfare. In the context of this academic paper, nudges are utilized to combat a economical bounded rationality issue. The term "bounded rationality" first introduced by Simon (1957) describes the phenom of human behavior arising due to limited cognitive power and knowledge. Due to these limitations humans often choose something that is satisfactory and not entirely optimal, because they do not have full information or knowledge to make optimal choices. With the introduction of the nudges in the case of this study, experiment subjects gain valuable information which is designed to help to choose optimally in terms of monetary benefit and behavior.

Many experiments mostly discuss the changes in human behavior, social incentives to alter the use of electricity and water, but little attention is paid to the market and prices even in the critical peak hours of the day. Moreover, there is little research on the impacts of informational, monetary and other kinds of nudges on the price level of the respective good. The response to social and monetary incentives is an important topic in a social sense, since if the target groups are essentially reactive to behavioral nudges the demand for electricity becomes more flexible with respect to the time of the day and socially optimal conservation objectives can be met successfully. Such behavioral nudges as peer comparisons have been gaining popularity recently due to their ability to impact choices without the change on the monetary side and to introduce the desired socially optimal behavior to consumer's lives. Furthermore, peer comparison is a natural way to evaluate decisions and actions which lack clear connection to the real world, so the way one can appropriately judge its action is by linking it to the actions of others, as stated in the famous work of Festinger (1954).

Moreover, the impact of social norms and moral pressure to act in a socially optimal way is broadly connected with the energy market as the use of the resource is a sensitive topic in a moral sense. For example, Schultz, Nolan, Cialdini, Goldstein and Griskevicius (2018) specifically match the decrease in electricity consumption of previously prodigal subjects to the impact of social norms. This moral norms problem is a part of many other researches to this day which record a brief decrease in consumption due to the powerful appeal to the social norms being introduced especially in a high consumption environment (Allcott, 2011; Ferraro and Price, 2013). The model of Taylor, Rollins and Lott (2018) has suggested that peer comparison messages introduce a moral cost of use of a scarce resource. I am particularly interested in what effect can informational interventions have on price. Researches by Jessoe and Rapson (2014) and Davis and Metcalf (2016) have indicated that information plays an important role in how prices influence consumer behavior in the energy sector thus enhancing the need for further research. In the experiment by Baltaduonis, Jaraitė and Kažukauskas (2022), which I have investigated, different type of incentives were used. One was deemed as monetary information and was produced in the form of notifications about surge prices of electricity and the other was a typical social incentive in the form of peer comparison. These different interventions were introduced in different ways – both separately and together with one another. The goal of this research is to fill the gap of papers investigating the effect of behavioral nudges on prices in a real market environment and to evaluate if the change in prices could have any meaningful price sensitivity effects when simulating real purchasing decisions. The aim of finding any meaningful relationship between nudges and prices revolves around running a random effects regression model to estimate the size and sign of the coefficients in order to evaluate the impact of nudges.

The data was collected from a laboratory experiment, the sessions of the experiment taking place over the months of April, May and September in the year 2021 (Baltaduonis et al., 2022). A simplified case of the actual electricity market case was being examined where the experiment focused on consumers' purchasing decisions at retail level with the simulated market being the only source of energy. This kind of experiment design is advantageous compared to a field experiment since lab experiment is the only method where it is feasible to simulate such settings and control for factors that would otherwise be unattended in a field experiment framework. The analysis conducted in my research differs from the research of Baltaduonis et al. (2022) as there the authors investigated the effects of the interventions on the overall market efficiency in the same setting. In contrast to the original experiment by Baltaduonis et al. (2022), I do not pay specific attention to critical demand days and resulting systemic supply shocks. The main research questions of my thesis are whether the nudges impact the prices in this setting and does the change

in price introduce different consumption patterns due to price sensitivity. The results indicate that peer comparison reports and surge price signals help to achieve a meaningful price lowering effect when applied both one at a time and especially together. Moreover, the interaction of these interventions and prices fails to achieve a statistically significant increase in price sensitivity.

The work is structured in the following way - the introduction to the research topic and the relevance of the research idea is followed by the review of the existing literature that could contribute to the relevance of the research and evaluation of the results. Then there is data section that aims to explain the nature of the experiment data and how the treatments were applied to possibly impact variables of interest. Further section covers the hypotheses of my research that were raised in order to distinguish the answers to the most important research questions. The econometric methods that were used to estimate the results and testing the hypotheses are then covered in the methodology section. Lastly, the results of the regression models are discussed and conclusions are drawn in the last few parts of the paper.

1. LITERATURE REVIEW

There exists a lack of literature specifically on the topic of how nudges impact the price level and price sensitivity of consumers which I am focusing on in this work. However, nudges have been gaining popularity among policy makers and researchers due to their effect on consumption, moral price introduction on behavior and possible complementary together with monetary measures.

Peer comparisons, behavioral nudges and other interventions induced to alter human behavior have been a powerful tool of suggesting more efficient, greener consumption choices. Unsurprisingly, there has been an increase in popularity of such applications as "Opower" and "WaterSmart Software" which provide personalized resource usage reports to consumers in an attempt to improve the efficiency of consumption in terms of monetary and social welfare of consumers. The market for electricity usage has been one of the key markets that has been targeted by policy makers and governments in terms of introduction of social nudges and comparisons. Social nudges have especially targeted demand management as the only way of how conservation can be encouraged. Conservation enhancement measures are one of the most popular uses of nudges in the existing literature. Allcott and Rogers (2014) and Brent, Cook and Olsen (2015) present that behavioral nudges go along with the conservation policies. Behavioral nudges are really powerful in affecting human perception as it directly removes any inconsistencies with the actual price and amount consumed. Various researches have provided us a glimpse that peer and other social comparisons can encourage energy conservation relatively effectively and even reduce the consumption by up to five percent (Allcott, 2011; Brent et al. 2015; Buckley, 2020; Ferraro and Price, 2013; Henry, Ferraro and Kontoleon, 2019). Peer comparison is one of the most widely used social nudges used to encourage conservation and it makes a lot of sense, since it provides awareness to the consumer about its own consumption and relative to its peer – both of the measures are relatively unknown to the average consumer (Buckley, 2020). In theory, more personalized information could achieve even more optimal conservation, but people are against it and usually do not like such demanding interventions. Nudges are particularly important as peer comparison gives an insight to how a person can benefit from conservation in private welfare. Generally, the reports have to present the information in clear and flexible way for consumers to find any link between daily life and conservation (Murtagh, Gatersleben and Uzzell, 2014). The possible positive impact of monitors displaying energy consumption also depends greatly on the fit in the house design as well as the fit in the social context of the household (Hargreaves, Nye

and Burgess, 2010). In fact, direct feedback on energy usage can help alter the behavior of the subject in a way that energy savings could even reach twenty percent (Faruqui, Sergici and Sharif, 2010). As Buckley (2020) pointed out, direct and clear, personalized feedback could even be more effective than pricing interventions and monetary strategies. On the other hand, the sole use of peer comparison reports of mean consumption have a tendency to encourage consumers with lower consumption to undesirably increase their use as explained by Bonan, Cattaneo, d'Adda and Tavoni (2020). From the social point of view, it is also important to examine the persistence of the desired effect introduced by the nudges in the long–term spectrum. There is less information on such long – term impacts. Bernedo, Ferraro and Price (2014) suggest that although the impact of social interventions declines significantly over time, it is still useful for policy implications even after a few years have passed. This has important social implications as they discuss the possible tweaks to the personal habits of consumption caused by an unexpectedly persistent intervention. If the nudges manage to introduce a persistent effect, they are also significantly less costly.

Moreover, as there is a lack of literature on the impact of nudges on the price, many authors focus on moral cost and the salience of moral decisions that is upgraded by nudges. As Allcott and Kessler (2019) suggest people value the morality aspect so much due to there being little relationship between prices and behavioral nudges. The relationship of prices and informational and monetary intervention is what I am trying to single out during my research. Jessoe, Lade. Loge and Spang (2021) particularly focus on the potential extensions of the impact of the intervention to the sectors that are unrelated to the generally targeted variable. If the impacts of the intended policy went over to other sectors, it could signal significantly larger welfare impact than thought previously. The finding that a policy aimed at water consumption also introduced a significant effect of up to two percent on electricity conservation suggests that the impact of nudges could even come up to provoking conservation habits similar to the ones caused by direct electricity consumption reduction policies or at least raise the moral behavior question. There is a lack of literature on whether the nudges could introduce such effects on price that could spill over to other scarce resources. Ayres, Raseman and Shih (2013) present that efficient use of nudges in the energy sector could translate to other sectors such as health and education thus increasing social welfare. Ito, Ida and Tanaka (2018) discuss the effect of moral suasion as a behavioral nudge relative to dynamic electricity pricing treatments. They find that moral suasion induces relatively big effects in the short run that come to an end quickly relative to dynamic prices that exhibit longer-run effects. Moral suasion seems to only be effective in the short run and can be introduced repeatedly in regular intervals and time-varying dynamic pricing has different long-run effects. In fact, Ito et al. (2018) shows that moral suasion managed to provoke an eight percent lower peak-

hour electricity use in the short-run. The moral aspect is also researched in studies where the subjects do not have a financial incentive to act morally – for example, they do not pay for their consumption directly. As explained by Myers and Souza (2020), the omission of monetary motivation can rule out the conservation effects caused by moral suasion. Essentially, moral nudges only have positive treatment if the introduced cost on morality exceeds the private energy costs at a given moment, as explained by Brent and Wichman (2020). Significantly to my research, (Allcott and Kessler, 2019) find that the relationship between moral, prosocial behavior should go in line with significant gains in welfare. Taylor et al. (2018) also discuss that the interventions that target moral cost could introduce positive welfare changes if the retail price of a resource is lower the social marginal cost.

The combination of the monetary and informational nudges is crucial in my research in search of the optimal result and is also one of the most important topics in the literature investigating the effectiveness of nudges. On the monetary side of things, Wichman (2017) points out that a higher frequency of information is not necessarily beneficial to the net welfare of the consumers as consumers can increase their consumption when they have a more transparent image of the prices they are going to pay. It is also needed to take into account the percentage of income that is saved – it simply might be too low for subjects to have any significant incentive to conserve. Moreover, it is particularly important to analyze the complementary relationship of different policies as various authors (Brandon, List, Metcalfe, Price and Rundhammer, 2019; Baltaduonis et al., 2022) suggest positive complementarity regarding the relationship of social nudges and economic incentives. Brent and Wichman (2020) show that little evidence was found to conclude that nudges interact with economic incentives, the relationship that will be further examined in this paper. Even if the interaction may look theoretically probable, improving the salience of economic interventions does not necessarily play a relevant role for behavioral interventions. To add, Fanghella, Ploner and Tavoni (2021) even discuss that the combination of financial bonus and informational feedback results in the nudge making a way for consumers to turn their attention away from the financial incentive and thus making it significantly less effective. Baltaduonis et al. (2022) however, suggest that the peer comparison nudges fail to achieve the desired effects and the only effective type of treatment was when both monetary and social type of incentives were involved. This is important for my topic since I am going to see how social nudges impact the monetary side – price level and sensitivity.

Regarding price level and sensitivity effects which were also investigated in my work, Brent and Wichman (2020) conducted an experiment researching similar effects in the water consumption market. Specifically, they wanted to find out if the purchasers who face higher prices

show a bigger reaction when a conservation campaign is ran showcasing their water consumption in reference to other households. The results in the paper in question do not show significant signs of this price–level effect. They also tested how this type of conservation campaign interacts with the price sensitivity of consumers. Crucially, weak evidence of price sensitivity effect was observed, although some demand elasticity was spotted in specific cases. Significant relationship between informational treatments and price would showcase that participants are responding to some extent to the increases in the private welfare benefits gained from conservation, knowing the amount of evidence that consumers in this environment do not have full information about prices (Wichman, 2017; Brent and Ward, 2019). It remains to be seen whether prices would interact with informational nudges in a clearer way if the economic benefits were bigger to the consumers. Ito et al. (2018) also discusses the fact that the economic benefits are not as visible to the consumers since they do not account for excessive usage during peak hours in monetary terms. When looking at price effects it is also important to distinguish the term introduced by Ito et al. (2018) which refers to hours immediately before or just after the peak hours. Not only should we desire more effective conservation during the peak demand hours, but also during these shoulder hours as for potential spillover effects not to negate the positive externalities introduced by moral nudges. Furthermore, Sudarshan (2017) suggests it is challenging to distinguish meaningful price sensitivity effects in the electricity market while changes in price are usually strongly related to other factors that could also influence consumption. However, the author of the respective work was able to find some evidence that peer comparisons reports provoked a larger reaction compared to the control group. Jessoe and Rapson (2014) also showcase that households that are subject to both changes in price and frequent informational interventions reduce their consumption by up to 22 percent while households that experienced increases in price lowered their consumption by up to 7 percent displaying large price sensitivity effect. On the other hand, Buckley and Llerena (2022) find significantly greater consumption in some periods in a higher price scenario compared to a nudge scenario where the consumption of the participants was evaluated against the socially optimal level. This implies weak price sensitivity.

2. DATA

2.1.Experimental design and environment

To showcase the design and the experimental environment I used the lab experiment by Baltaduonis et al. (2022). Two hundred participants who were undergraduate students from Gettysburg College were randomly selected from the student list to take part in the experiment. All experimental sessions were conducted in Gettysburg Lab for Experimental Economics (GLEE) over the months of April, May and September in the year 2021. A lab experiment was used because there exists no practical way of conducting such a research in the field experiment setting. This environment allowed for more convenient testing on the relationship between the variables and removed the dependance on the background which field experiments could be subject to. In total, twenty four thousand (24,000.00) observations showcasing the daily consumer decisions were collected over the span of the experiment. These observations include the pre-treatment phase and all of the treatment phases. Each session was made up of 120 periods which included the so called "treatment days" in 15 experimental months. As there were only two active weeks in the month, each month consisted of 8 periods that were called as days (Baltaduonis et al., 2022). In the experiment, a simplified representation of the electricity market was created. The simulated environment makes the market the sole place to buy any energy and the use of the bought electricity is not replaceable between time. Furthermore, it is crucial to note that the participants were purchasing unspecified units. Consequently, they did not know that a simulation of a retail electricity market was being run. This circumstance prevents the subjects from applying the expected social norms and moral costs to their consumption behavior and helps to have a clearer look on specific price level and price sensitivity effects. Concerning the environment of the experiment, the periods are split into days. The number of consumers in the experiment who participate in the market is limited to four. Each day they have a choice of units which can be bought. Only four occasions of these days happen in one week and two of those weeks are set to happen in a month. After the month ends, the subjects receive a bill reflecting the decisions they have committed in the market for that month. The experiment was ongoing for 15 such months. Days in a week are separated by demand and time of the day that is set in the specific days. Day 1 is specified as an off-peak period (night time, low demand), Day 2 is a shoulder hour period (morning hours, demand is medium), Day 3 is specified as a peak period (afternoon, the demand is at its peak - high) and Day 4 is what follows after a peak period – another shoulder hour period (evening hours, medium demand). It is not surprising that these "days" are constructed similarly to the usual electricity usage cycle during the day – they reflect the usual demand movements over

the course of the 24 hours. Furthermore, as the market has to be cleared, the price is set by the most expensive supplier offer that enables demand to be met each hour.

Peak demand hours require specific attention as price sensitivity is especially important in the most sensitive, highest demand, highest price period. This period corresponds to Day 3 in the experiment. The marginal benefit gained from consuming a purchased good during a purchasing period is distributed in such a way that the market demand is inelastic. Furthermore, the market participants have no incentive to move away from the consumption level that is set by the competitive equilibrium in the market. On shoulder hour demand days, the demand is equal for both of the days. However, the units that can be purchased in the experiment can only be attributed once to the same buyer over the course of these identical demand days. The center of attention of this experiment is specifically on demand-side behavior in varying information setting which can cause a monetary impact on price.

2.2.Information

All of the subjects of the experiments know about the upcoming marginal benefit due to the consumption of the unit. On the other hand, they do not have the information of the values of the benefits that are available to any other subjects of the experiment. However, the marginal costs on the supply side are available for the buyers since the wholesale unit price is presented to the subjects of the experiment instantaneously. Due to that, buyers have the knowledge that aggregate demand is the determining factor of the market price during any of the buying periods. The subjects of the experiment also know that they are contracted under the FRP (flat-rate pricing) pricing contract. In this type of contract all of the costs that are associated with production are divided evenly across the total sum of units produced. The time of the purchase is not taken into consideration. A uniform price per unit is calculated by taking the weighted average of the market prices over the course of the whole month and this price is paid for all purchases during the month. Such pricing contract keeps consumers relatively safe from any fluctuations in the market. The price paid for the units purchased during that month is uniform, but the market prices are subject to great variability over the period and they impact the monthly price directly in the formula.

To further diagnose the effect of social information effects on the level of price and price sensitivity, four treatments were introduced in a between-subject design. The baseline treatment (T1) does not involve any informational interventions supply while all other three treatments include some kind of instances of different behavioral settings starting from Month 6 until Month 15. Different informational treatments are listed below as follows:

Treatment 1 (T1): No peer comparison and no messages about surge pricing

Treatment 2 (T2): peer comparisons

Treatment 3 (T3): messages about surge pricing but no peer comparisons

Treatment 4 (T4): messages about surge pricing and peer comparisons

Learning period is significant in these types of experiments, so the mentioned treatments only began in Month 6 and the pre-treatment phase is not included. This allows for easier understanding of the actual effect of the treatment and allows to witness if the behavior showed any relevant changes that introduced effects on price levels. This design also helps to maintain the behavior in the pre-treatment months stable and fluctuations in the behavior after treatment are more visible.

Peak demand period is undoubtedly the most important period when examining price level and price sensitivity effects in the experiment. Notifications announcing the upcoming crucial peak demand periods are displayed to the subjects for this specific matter – to cause more attention and to successfully measure the price effects of such notifications. One of the theoretical liabilities of the experiment design is that these price surge notifications about peak periods do not amount to much for a buyer that is looking to maximize his surplus from consumption, as the uniform price paid is a result coming from the choices made by all consumers during the course of the month. Behavioral nudges are provided as peer comparisons in the experiment and these nudges are in effect in treatment groups T2 and T4. This information is available for the buyers by clicking a specific button on their screens. It includes information on their own purchases on any day of any specified week and past market averages.

The experiment subjects were paid a fee for showing up to the experiment which amounted to 10 USD. Additionally, any earnings made during the experiment were left for the participants to keep. The mean earnings of the participants amounted to 11.23 USD during the experiment, without summing up the show-up fee of 10.00 USD. Earnings were in the range between 0.00 USD and 18.75 USD not including the show-up fee. Each participant was randomly seated at one of the computer terminal stations. From any of the computer stations there was no possibility to view the computer of the other buyer. A recorded video of the instructions was shown to the participants at the start of each session. Additionally, paper instructions were present. On every decision-making screen, the participants had to click on “Purchase Unit” buttons one two times in a row to commit to buying units. If participants wanted to void any of the purchases they had made, they were able to do so by clicking the “Undo Purchase” buttons. A 15 second time limit was set to make the decision on how many units a buyer wants to consume on a particular day. On the screens, the participants were able to view their current balance, the number of units they had

already bought, the resale revenue of these already bought units, the market price per unit. However, participants were not able to see their accumulated profit, costs or flat price per unit – as discussed, this price was only determined after all of the decisions of the month were already done for consumers. At the end of each month, participants received a monthly bill, which displayed the mentioned price per unit calculated as the weighted average of the market prices during the month. Consumers also got to know the total amount of units purchased, total revenue gained from resale, total costs, total profit, total monthly profit, and information on their updated current balance in the account (Baltaduonis et al.,2022)

2.3.Hypotheses

The goal in the experiment was to see whether informational and monetary nudges could have a significant effect on lowering the price of the good. Additionally, it is important to determine whether the treatments have an impact when applied alone or they achieve the largest value when combined together. The first hypothesis is that the application of nudges has a significant effect on price and the effect is stronger when both type of nudges are in effect together(T4) compared to the case when a single type of nudge is in effect(T2/T3). This hypothesis is based on similar works showing the effectiveness of nudges, especially when applied in combination(Baltaduonis et al., 2022; Brandon et al.,2019). Additionally, I chose to explore the price sensitivity effect when determining if the quantity purchased reacted meaningfully to the changes in price. Therefore, the second hypothesis of my research is that there exists a significant price sensitivity effect – the quantity purchased is reactive to the changes in price which interact with the applied nudges.

2.4.Descriptive statistics

In this section I am going to report the descriptive analysis of the data and the most important variables – the descriptive statistics of the four dummy variables representing the treatments and the statistics for the monthly price and purchased units variables. In Table 1, I present the mean values for monthly purchased units and monthly price – the two variables determining the price sensitivity effect. Average monthly price observation for each of the four treatment groups is presented. Each treatment group involves 10 independent markets with 4 individual buyers each. The treatment phase lasts for 10 experimental months leading up to 400 total observations. The values reported are exclusively from the treatment period of the experiment (Months 6-15) separating the different treatments that were applied. Each of the treatments was used in a 100 of observations. On average, the lowest price level is observed in T4, when both price surge notifications and peer comparison reports were in effect. Otherwise, T1 group has

shown the highest average monthly price unsurprisingly, as in this period no nudges were applied, it is a baseline scenario. The standard deviation values show that the highest deviation among prices is found in the T1 group.

Table 1

Average purchased units and prices with different treatment interventions

	T1	T2	T3	T4
Mean monthly purchases	16.98	17.31	16.02	16.46
Average monthly price	183.7	159.84	144.89	129.82
SD monthly purchases	8.39	7.48	8.98	7.90
SD monthly price	107.2	58.47	69.22	26.86

Source: prepared by the author based on the research.

3. METHODOLOGY

3.1.Price level effect

To capture the effects of the nudges on the prices in this experiment, I conducted two kinds of regression models to showcase the versatility of the results I was able to obtain and the general applicability of these results in a broader scale environment. Firstly, I estimated an Ordinary Least Squares regression model to examine the possible differences in prices between the treatment groups and the general difference of applying any kind of nudge in comparison to the baseline case where no treatments were in effect. Furthermore, I estimated a random effects regression model having the same goal in sight to check which of the models was more applicable to the experiment data and provided clearer and more significant answers to my research question. The analysis only consisted of the data from the treatment days which started from the 6^{th} experimental month and lasted until the end of the experiment. The "learning" part of the experiment which can be thought of as the months until the 6^{th} experimental month was not included in the analysis. The baseline case is referred to as the treatment T1. In this case neither the peer comparison, neither the messages about surge pricing events were provided. The discussed OLS model was the following:

$$P = a_1 + a_2 T_2 + a_3 T_3 + a_4 T_4 \quad (1)$$

In this model, the *P* stands for the monthly price of the unit which is generated at the end of each month after all of the purchases of the subjects have been made. The monthly price was calculated as the weighted average of the market prices over the course of the month. The constant term is defined as a_1 and T_n, where n obtains the values from 2 to 4 is the term referring to treatments from treatment 2 to treatment 4 and suggesting if the subject is included in any of these three treatment groups. As explained above, T1 is not included in the analysis and is considered the baseline case for the model. Moreover, a_m is a term that shows the mean causal treatment effects that are induced by the monetary and informational nudges on the monthly price level in the experiment.

Furthermore, I conducted a random effects regression model to test out the validity of the OLS in terms of the effect and possibly enhance the model performance. The random effects regression model was the following:

$$P = a_1 + a_2 T_2 + a_3 T_3 + a_4 T_4 + u_i + \nu_i \quad (2)$$

In this model the main difference in terms of the variables from the OLS case is that there exists a random effect term – u_i. It permits the slope of the regression line to vary between different subjects of the experiment in the regression model. The main idea of this term is to assemble any reasonable differences that fail to be explained by the independent variables. Moreover, there exists an idiosyncratic error term ν_i which aims to explain the variation in the model that is not explained by the independent variables or the random effects variable. The term is assumed to be independently and identically distributed and has mean =0. It is assumed to be not correlated with the other explanatory variables in the model and has constant variance across all of observations. For the main model estimating the effect of nudges on the monthly price, "Swar" (Swamy and Arora, 1972) random effects estimation method was used. This model is efficient when estimating variance in such models and accounting for possible heteroskedasticity. The random effects are normally distributed with mean=0.

To calculate the monthly price, the market price is per unit is used. Therefore it is important to present how it is determined in this experiment setting. Market price per unit is calculated at the point where market demands equalizes market supply. As market price is so dependent on the demand of the units in each period, it can vary noticeably during the month. Unlike the monthly prices, the market prices are displayed to the consumers in real time, not at the end of the month. The market price is then used in the calculation of the monthly price per unit.

The main variable of interest in my research is the monthly price. In the experiment of Baltaduonis et al. (2022) it was calculated as follows:

(The Sum of Units Purchased in Day 1* Market Price per Unit in Day 1)+(The Sum of Units Purchased in Day 2* Market Price per Unit in Day 2)+…+ (The Sum of Units Purchased in Day 8* Market Price per Unit in Day 8)

(The Sum of Units Purchased in Day 1+…..+The Sum of Units Purchased in Day 8)

3.2.Price sensitivity effect

Seeking to capture the price sensitivity effect, I utilized a random effects regression model. The regression equation was formed in the following way:

$$\underline{W=P_{(t-1)}T_2+P_{(t-1)}T_3+P_{(t-1)}T_4+u_i+v_i} \quad (3)$$

In this random effects regression model, W is equal to monthly purchased units. It is estimated using a lagged monthly priced variable P(t-1) where (t-1) accounts for a lag of one monthly period or eight experimental days in the experiment. To represent the effect of nudges, lagged prices were multiplied by a treatment effect which signaled an interaction term. Identically

to equation (2) there are two different error terms in the regression model – u_i and v_i. The model utilized a "Walhus" random effects estimation method investigated by Wallace and Hussain (1969). In this method, variances of the error components are firstly assumed to be known. Then the estimators obtained through generalized least squares are compared with estimators generated by transforming the covariance, taking into consideration different assumptions regarding the independent regression variables. Then a case where the variances are unknown is examined. An iterative estimation approach is proposed, and the properties of the estimates obtained through this iterative process are compared with estimators based on covariance estimation methods as explained by Wallace and Hussain (1969)

4. RESULTS

4.1.The effect of interventions on price level.

To begin with, I consider the OLS (Ordinary Least Squares) model version. Table 2 displays the effects the treatments induce on the monthly price, where "YesMsg" stands for both the surge price notification and peer comparison informational interventions(T4), "NoMsg" displays the treatment of only receiving peer comparison information(T2) and "YesMsgNoAve" is equivalent to T3 treatment of receiving a surge price notification but not the peer comparison report. The regression does not focus on specific demand periods to diagnose the further effect on price. The model is designed to showcase the general effect of nudges on price in the treatment phase.

Table 2

Effects of the nudges on price explained by OLS regression.

Price level effect with nudges from OLS regression	
	Dependent variable:
	month_Price
	Coefficient
T4	-53.888***
	(10.106)
T2	-23.865**
	(10.106)
T3	-38.814***
	(10.106)
Constant	183.708***
	(7.146)
Observations	400
R^2	0.073
Adjusted R^2	0.066
Residual Std. Error	71.457 (df = 396)
F Statistic	10.334*** (df = 3; 396)
Note:	*p<0.1; **p<0.05; ***p<0.01

Source: prepared by the author based on the research.

In Table 3 I present the regression output generated by the random effects regression model. The treatment variables used are the same as in the OLS regression model. As displayed by the magnitude and the sign of the corresponding coefficients, the models do not differ in any significant way from each other. The statistical significance is also the same in both of the models as the only variable that would not be statistically significant at 99% confidence level is the T2 variable. The standard errors differ insignificantly between the two models and the goodness of fit measure is also relatively similar. This concludes that the random effects model is a viable choice in this case. As the treatments in the experiment are completely random, the individual and idiosyncratic error terms are not corelated with any of the treatments, so the random effects model is not subject to endogeneity problems. The nature of the experiment combats the possibility of the coefficients being inconsistent or biased.

Table 3

Effects of the nudges on price explained by random effects regression.

Price level effect with nudges from random effects regression

	Dependent variable:
	month_Price
	Coefficient
T4	-53.888***
	(9.337)
T2	-23.865**
	(9.337)
T3	-38.814***
	(9.337)
Constant	183.708***
	(11.217)
Observations	400
R^2	0.084
Adjusted R^2	0.077
F Statistic	36.318***
Note:	*p<0.1; **p<0.05; ***p<0.01

Source: prepared by the author based on the research.

The size and the significance of the coefficients firmly suggests that there is a significant price lowering effect that is exhibited by the informational interventions. Consistently with the findings of Baltaduonis et al. (2022), the biggest effect on the dependent variable was found when both of the informational treatments were applied at the same time. The effect is more than two times bigger compared to the case when only peer comparison is provided. It is also visible that even though both of the effects are significant, receiving a price surge notification (T3) has a bigger effect on monthly price than receiving an average consumption peer comparison report (T2).

4.2.The effect of nudges on price sensitivity.

The second hypothesis of my thesis is that the nudges induce higher price sensitivity. To determine this effect I used a random effects regression model in which I set the purchased units during the month(month_Pur) as a dependent variable and monthly price(month_Price) as the independent variable together with the interaction terms of specific treatment interventions. Table 4 suggests that there exists a negative interaction between the nudges and the units purchased, however the only stand out and significant interaction between purchased units and nudges is observed when applying T4 – both monetary and peer comparison interventions together. Furthermore, the price interaction terms with all of the treatments are positive. These results firmly suggests an endogeneity problem, as the treatments not only affect the price of the unit, but also the purchased units, so the real relationship between prices and purchased units is unclear in this setting.

Table 4

Price sensitivity effect with all treatments applied.

Price sensititvity effect from the same month with all treatments	
	Dependent variable:
	month_Pur
	Coefficient
month_Price	-0.001
	(0.007)
T4	-26.785***
	(4.007)
T3	-4.418*
	(2.283)
T2	-1.832
	(2.643)
month_Price:T4	0.190***
	(0.029)
month_Price:T3	0.004
	(0.013)
month_Price:T2	0.020
	(0.015)
Constant	68.203***
	(1.708)
Observations	400
R^2	0.159
Adjusted R^2	0.144
F Statistic	74.344***
Note:	*p<0.1; **p<0.05; ***p<0.01

Source: prepared by the author based on the research.

Regarding the methodology of price sensitivity analysis, adjustments to the data sample have been made to avoid this potential endogeneity problem. I used a lag of one experimental month on the prices of the units. Knowing that the subjects of the experiment would only receive their bills after the end of the month, they can alter their behavior only in the next period. Using this method, the perception of prices is clear and subjects of the experiment have time to adjust

their consumption according to price. This allows to measure if the consumers are indeed sensitive to changes in price.

The coefficients suggest a weak and insignificant relationship between purchased units and prices and the subjects seem to be insensitive to price in their consumption as the price coefficient is not significantly different from zero (-0.001). The interaction term is positive consistently with the non-lagged case, but the treatment coefficients have shrunk in size suggesting a successful measure against endogeneity. A large shift in magnitude and significance for the T4 coefficient also suggests that direct relationship was subject to endogeneity. Although the impact of nudges to the price level was clear within every treatment, such change does not meaningfully impact the consumption behavior in any of the treatments. T2 (NoMsg) and T3 (YesMsgNoAve) treatments show impact of similar magnitude as the T4 coefficient on purchased units. This consistency implies that the nudges are not powerful enough to introduce price sensitivity effect both alone and in combination. The goodness of fit measure also implies that there is indeed a lack of control variables to explain the decisions and the price is not the main driving force explaining the consumption. Generally, the method fails to display any reasonable price sensitivity effect which would be significantly different from zero. This is also consistent with the findings of Brent and Wichman (2020).

There could be several reasons why the effect on prices does not translate to much on the purchased units suggesting no meaningful price sensitivity effect. Firstly, it could be that the knowledge of only the prices from the previous period is not enough to change the behavior and have weak explanatory power of the purchasing decisions during the next month. I have investigated this relationship in other proximity and designed a regression to see if the effects are different when the information about prices is taken from the first five experimental months giving more time to form a perception about possible prices. There also exists a positive interaction term between prices and nudges. Please see the Appendix section for these results. Given the insignificant impact of the prices to the purchased units, it is hard to distinguish any meaningful price sensitivity effect in any time period using lagged prices from the previous months. It also could be that the lab experiment environment has an impact on sensitivity, as a 15 second timer could exert time pressure effects which would rather provoke insensitive decisions. Another possible reason why the price sensitivity effect does not coincide well with the effect on price is that the effect on price might still be too little in terms of welfare for consumers to change their consumption.

Table 5

Price sensitivity effect with all nudges with lagged price included.

Price sensititvity effect with all treatments	
	Dependent variable:
	month_Pur
	Coefficient
Lag_price	0.001
	(0.020)
T4	-2.944
	(4.061)
T3	-4.465
	(3.373)
T2	-0.770
	(3.770)
Lag_price:T4	0.007
	(0.027)
Lag_price:T3	0.003
	(0.021)
Lag_price:T2	0.017
	(0.025)
Constant	67.775***
	(3.175)
Observations	392
R^2	0.084
Adjusted R^2	0.067
F Statistic	27.431***
Note:	*p<0.1; **p<0.05; ***p<0.01

Source: prepared by the author based on the research.

CONCLUSIONS

To this day, a lot of field experiments have been done to diagnose the effects of monetary and informational interventions to optimize human behavior. Although nudges are popular and even used nationwide by policy makers, there is lack of information on how they could interact with the prices of frequently used resources in order to provoke socially optimal and welfare maximizing consumption behavior. Additionally, this paper involves nudges as a tool against the bounded rationality issue in order to improve knowledge which would otherwise be taken less care of. This research thesis is designed to showcase how specific behavioral interventions could intervene in adjusting the price and whether the adjustments in price level have a significant effect on purchasing habits. Involving two different monetary and non- monetary interventions – surge price messages and peer comparison reports, I have found that both of these interventions help to significantly lower the price level. Similarly to other researches (Baltaduonis et al., 2022) the biggest effect was achieved when applying the two treatments together while surge price notifications were the second most effective intervention. Furthermore, I have investigated the effect the nudges have on consumer's price sensitivity. I found no evidence of such effect – if anything, prices and nudges interact together in a way that provokes purchasing in a positive way and does not dampen it. This is suggested by the positive interaction coefficient between treatments and lagged monthly price level. One way to explain the lack of price sensitivity is the possibility that the welfare gain from conservation of electricity is too low for consumers to significantly impact their use. This leaves a gap for further investigation of the relationship between prices and nudges in other experiments which could introduce bigger financial benefits. Another reason why I failed to find significant price sensitivity effects is that the lagged price could be a weak instrument in explaining purchasing behavior in the upcoming month. In addition to that, when applying the same lagging technique for a longer period to give people more time to make the adjustments, no significant effects were also found. Given the nature of the experiment, the limited time to make purchasing decisions could also have played a role in consumption not adjusting as much with respect to the changes in price. The experiment was also designed to intentionally omit the moral cost of consumption and social provocation to act in optimal way. Taking into consideration that the vast majority of literature suggests that moral costs are present and my findings imply that the changes in price or, in other words, direct cost of consumption, are not sufficient to introduce new purchasing habits, it remains to be seen whether social pressure is legitimately more impactful in changing the human behavior or other instruments could make the subjects as sensitive to price as they might be sensitive to the enforcement of acting in a moral way.

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THE EFFECT OF NUDGES ON PRICES AND PRICE SENSITIVITY IN A RETAIL ELECTRICITY MARKET ENVIRONMENT

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Bachelor Thesis

Quantitative Economics

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Summary

33 pages, 5 tables, 34 references.

The goal of this thesis was to research the possible effects of nudges on prices and to see if the change in prices has meaningful price sensitivity effect on consumer's decisions. The research was motivated by the existing lack of literature on this specific interaction and the increasing popularity of nudges in policy making suggesting that socially optimal and positive welfare introducing outcomes can be achieved. Considering this theoretical motivation, the research introduced econometric models to explore the effects on price level and sensitivity using a laboratory experiment data and specific framework simulating the real retail electricity market. The academic paper contains six main parts: introduction, literature review, data description, methodology, results and conclusions.

The introduction section introduces the reader to the concept of a nudge and its improving applicability in today's world. In this section I also present the main goals of the research and what value could they to the topic. Furthermore, I also give an overview of the data that was used in the experiment and what separates my research from other similar studies.

In the literature review section I present an rundown of different topics that are related to the usage of nudges and pricing as well as present papers that have answered similar research questions. Such topics as the effect of nudges on consumption, moral cost introduction by nudges and the complementary relationship of behavioral nudges and monetary incentives are covered and related research is discussed.

The data section provides the reader with more accurate representation of the simulated market framework. It also informs the reader on the treatments the experiment subjects were introduced to simulate informational and monetary interventions and the research hypotheses that were examined using econometric methods.

The methodology part explains the models that were used to examine price level and sensitivity effects as well as introducing the methods and differences between them. OLS and random effect regression models were used in the research.

The results chapter investigates the findings of the regression models and comments on the significance of the regression outcomes. The results part suggests that there exists a meaningful price lowering effect exhibited by the combination of both peer comparison and price surge notifications interventions. Those interventions also impact the price negatively when used alone. However, the treatments on price do not introduce meaningful price sensitivity effects. Lastly, the conclusions section discusses the provided answers to the stated hypotheses and lists the possible adjustments that can be made in order to improve further researches on the topic and states the possible reasons why a significantly higher price sensitivity effect was failed to be found.

PINIGINIŲ IR INFORMACINIŲ DIRGIKLIŲ POVEIKIS KAINOMS IR ELASTINGUMUI KAINOS ATŽVILGIU MAŽMENINĖJE ELEKTROS ENERGIJOS RINKOJE

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Vilnius, 2023

Santrauka

33 puslapiai, 5 lentelės, 34 šaltiniai.

Šio baigiamojo darbo tikslas yra išnagrinėti galimą informacinių ir piniginių dirgiklių poveikį kainai tiriant galimus kainos lygio pasikeitimus ir jautrumą pasikeitusiai kainai. Pasirinkta darbo tema yra motyvuojama tuo, jog yra juntamas stygius mokslinių tyrimų tiriančių būtent poveikį kainoms, nors įvairių informacinių dirgiklių naudojimas yra vis dažnesnis reiškinys. Remiantis pateiktomis teorinėmis dingstimis atlikti tyrimą, tiriant informacinių ir finansinių dirgiklių poveikį kainoms ir prekės paklausai kintančiai dėl kintančios kainos buvo pasitelkti ekonometriniai modeliai. Duomenys naudojami baigiamajame darbe yra paimti iš laboratorinio eksperimento, kuriame buvo simuliuojama tikroviška elektros rinka. Baigiamąjį darbą sudaro šešios pagrindinės dalys: įžanga, literatūros apžvalga, duomenų ir laboratorinio eksperimento pritaikymo apžvalga, tyrimo metodologija, rezultatai, išvados.

Įžangoje atkreipiamas dėmesys į plintantį įvairių dirgiklių naudojimą siekiant optimizuoti vartojimą, atkreipti dėmesį į moralinius veiksnius taip skatinant asmenis atsakingiau ir optimaliau vartoti elektrą ir kitas medžiagas. Taip pat apibrėžiama tokio dirgiklio sąvoka. Taip pat įžangoje pristatomi pagrindiniai baigiamojo darbo tikslai ir jų aktualumas remiantis egzistuojančiais tyrimais panašia tema.

Literatūros apžvalgos dalyje apžvelgiami įvairūs moksliniai darbai kurie perteikia dirgiklių poveikį vartojimui, vartotojo moralaus elgesio išryškinimui, diskutuojama apie skirtingų dirgiklių sąveiką kartu ir pateikiami esami tyrimai išryškinantys dirgiklių efektą kainos jautrumui.

Duomenų apžvalgos skiltyje plačiau apžvelgiamas pasitelktas laboratorinis eksperimentas ir pateikiamas jo tyrimo išskirtinumas lyginant su kitais panašiais moksliniais darbais. Taip pat iškeliamos hipotezės, kurias siekiama ištirti naudojant ekonometrinius modelius.

Metodologijos sekcijoje detaliau analizuojami pasitelkti modeliai ir kintamieji, taip pat metodai, kurie buvo pasitelkti siekiant kuo efektyviau atsakyti į hipotezėse keliamus klausimus ir jų naudojimo ypatumai bei skirtumai.

Rezultatų skiltyje apžvelgiami gauti regresijų rezultatai pagal pasitelktus metodus, pateikiami apibendrinimai remiantis gautais rezultatais ir galimos tokių rezultatų priežastys. Apibendrinant rezultatus galima teigti, jog egzistuoja statistiškai reikšmingas informacinių ir finansinių dirgiklių poveikis kainos mažinimui, labiausiai pasireiškiantis tuomet, kai ir finansiniai ir informaciniai dirgikliai veikia vienu metu. Nepaisant to, šių dirgiklių naudojimas veikiant kainą neparodo jokio reikšmingo pokyčio kainos jautrumui. Paskutinėje baigiamojo darbo dalyje pateikiamos išvados, atsakoma į iškeltas hipotezes ir aprašomi galimi trūkumai, kuriuos ištaisius galima būtų atlikti tolesnius tyrimus ir efektyviau ištirti norimus efektus.

Appendix

Appendix Table 6

Price sensitivity effect with lagged prices and all nudges in a longer time frame.

Price sensititvity effect from a longer time frame

	Dependent variable:
	Lag_pur_11_15
	Coefficient
Lag_price_6_10	-0.009
	(0.022)
T4	-24.543***
	(6.466)
T3	-0.144
	(4.764)
T2	1.816
	(6.557)
Lag_price_6_10:T4	0.170***
	(0.044)
Lag_price_6_10:T3	-0.026
	(0.028)
Lag_price_6_10:T2	0.005
	(0.042)
Constant	68.974***
	(4.084)
Observations	200
R^2	0.179
Adjusted R^2	0.149
F Statistic	41.781***
Note:	*p<0.1; **p<0.05; ***p<0.01