Behavioural insights into energy consumption in times of crisis

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Abstract

This paper aims to provide a perspective on the way scientific evidence collected in times of crises can inform current debates in the literature on energy consumer behaviour, but also the decision-making process. Data such as the one that resulted from our quasi-experimental interventions in Romania during overlapping crises such as the COVID-19 pandemics and the full-scale invasion of Ukraine—affecting energy prices and consumer behaviour. While we acknowledge the well documented challenges of replicating pilot studies based on convenient sampling to full population surveys, we also suggest that the latter are ultimately a feasible and cost-effective measurement of changes in contexts of sudden shocks. Such data collection efforts could become the object of an ongoing multi-stakeholder engagement process leading to better-designed and deployed policies that can deliver much better in both short-term goals (e.g. managing price fluctuations in energy crises) and more medium and long-term scenarios (e.g. just energy transition).

Keywords: energy consumer behaviour, quasi-experimental survey, Romania, COVID-19, crisis

1. Introduction

Crises that affect energy consumption are extremely diverse – from climate change effects [11, 6, 13, 4] to other natural disasters such as earthquakes [10], from war [9] to the COVID-19 pandemic [2]. Such unexpected circumstances lead to unexpected behavioral patterns in energy consumption, which in turn make policy measures less effective if left unadjusted in real time. However, as Parag et al [9] acknowledge, it is often the case that research "done too quickly, without adequate attention to existing knowledge, methodological rigor, best practice in research design and research ethics, can lead to poor quality results" [9].

Two years after the war in Ukraine started, Eastern European energy markets are still highly susceptible to various shocks, and as such there is a large need for new ways to measure energy consumption behavior in times of crisis in real time. In contrast to more sophisticated energy suppliers, Eastern Europe still faces many challenges in understanding its consumer behavior, given the absence of such measurement tools as smart meters or past studies that could offer a baseline for comparing demand fluctuations in times of crisis.

We explored the extent to which we can draw actionable insights from energy consumers in times of crisis, by implementing a large quasi-experimental survey assessing the impact of various interventions (e.g. information, social norms). Following Bahmanyar et al [2], we wanted to see the extent to which COVID-19 and the full-scale invasion of Ukraine have affected energy consumption behavior in household consumers in Romania. While several papers have covered the impact of COVID-19 pandemic on energy consumption in both residential [3, 14] and industrial [7] consumers in Central and Eastern Europe (CEE), there is no large-scale, experimental analysis to date published in peer-reviewed journals. Also, no past paper has accounted for the overlapping dynamics of the crises in this region, as the end of the pandemic overlapped with the beginning of the neighboring war in Ukraine and disruption of energy supply chains.

With the support of the largest energy provider in Romania—Electrica Furnizare SA, we implemented a multi-layered quasi-experimental intervention, delivered both online and offline to a large observable sample, between April and September 2022 to identify the best approaches for a short-term design of interventions targeting consumer behavior in times of crisis.

While much of the literature on energy consumption in times of crisis covers the extent to which policymakers should account for crisis-induced changes in energy outcomes [2,3], we

argue that private sector adjustments are also necessary as the direct interface with consumers. A better co-design process between public and private sector actors could result in better and more agile responses to market volatility, price fluctuations, and behavioral changes. A robust ongoing process of data collection can lead to the development of ready-made solutions in advance of energy crises, rather than in response to them. Our analysis is also aimed to respond to the inherent limitations of transplanting findings beyond laboratory settings (e.g. validity), as well as to the challenges of expanding from convenience samples [16, 17, 18]. That is why we tested a methodological approach that was designed to expand from online pilot studies to large offline population experiments.

Socio-economic differentiators or consumer behavioral segmentation has been reflected in most energy consumption studies, albeit not in all explicitly - see for recent examples [1, 15, 8]. Our quasi-experimental intervention equally reflected robust results in socio-economic differentiators on consumer behavior, especially on the income levels—as per the price fluctuations chart, and between urban and rural energy consumers. We believe such behavioral segmentation is highly relevant for targeted measures in times of crises, rather than the blanket measures that most of the CEE countries, like Romania, have instituted. Blanket policy measures are usually preferred in the absence of operational data on consumer segmentation, and that is why high-quality statistical evidence on the socio-economic profiles of households and individual consumers should be triangulated with recent evidence from behavioral studies such as the quasi-experiment we have implemented. Only putting together these types of data can inform the optimal social assistance policies in energy consumption targeting energy poverty. For example, in this population quasi-experiment, we found that there is a highly significant segmentation in the low energy consumption profile, between households facing energy poverty and households where the socio-economic profile of members is that of professionals spending little time at home. The methodology that we implemented, mixing online with offline survey waves, allowed us to pinpoint various household specificities that move beyond counties or cities, which in turn could prove to be highly influencial on the household's potential to reduce their energy consumption [19].

However, there are neutralizing effects of the type of analysis we conducted. Firstly, there are overlapping crises, as our targeted population was not facing just the COVID-19 pandemic, but also a global rise in energy prices and other direct and indirect repercussions of the war in the neighboring country of Ukraine and a process of domestic energy price liberalization. This overlapping nature of contemporary crises makes effects and causal relations more uncertain

than in past studies on the consequences of singular events such as an earthquake [10]. Secondly, our data showcases once more the limitations of scaling pilot methodologies such as online surveys to real population samples. The capacity limitations in implementation are only a part of the challenge, as comparability and traceability of sample populations are also hard to attain. Finally, the agility of implementation is a third issue in large population interventions such as the one we implemented, as its preparation took several months and accounted for the effects of the full-scale invasion of Ukraine or the COVID-19 pandemic by coincidence, its target initially being only the baseline assessment of energy consumer behavior in a market that was under-researched. Given the extraordinary context of multiple crises, we are still left without an ordinary reference point of normal consumer behavior trajectories in Romania.

2. Methods and Results

Between April and September 2022, the Romanian energy provider Electrica Furnizare SA applied a set of online and in-bill RCT and RCT-variation interventions to their customers to test the effect on household consumption of several social norms information incentives. To help design these interventions along a manageable number of meaningful topics, a foregoing online survey based on 38 question sets was applied between 19 November and 4 December 2021 to a representative sample of own customers with active online accounts from all regions of Romania (n=1179). The survey was delivered via e-mail. Its main objective was to identify what are the preferred motivators for energy consumption reduction. Additionally, the survey collected other consumption behavior-related information and socio-economic data needed for the refinement of the research instruments. The survey had a 15% response rate and pointed out the relevance of at least 3 types of values concerning energy consumption, in the following order: (1) energy price; (2) household wellbeing; (3) environmental effects, each with specific nuances. We designed, as a result, four types of social norm interventions to inform households about (1) possible financial gains related to consumption reduction through an "individual benefit intervention"; (2a) individual and (2b) collective health impact through an "individual" and "collective information intervention"; (3) environmental effects phrased in an altruistic social norm intervention through an "altruism and social norm intervention".

We tested these interventions in an online experiment on a sample of customers (n=30.645) selected along demographic characteristics (age, location, consumption interval) to reflect the overall Electrica client pool. Three inclusion criteria were applied: the client has an online billing contract; either possesses a smart meter or has reported the consumption index in at

least eleven out of the twelve months for each of the 2 years before the intervention; the client has a GDPR agreement in favor of data collection. The intervention was sent out through e-mail in three one-off monthly interventions (April, May and June 2022), which included four randomly created intervention groups of similar size (n1=5687; n2a=5315; n2b=4280; n3=5524) and composition, and a control group. The impact was measured on monthly consumption after every intervention.

The survey platform was programmed to account for the number of accesses per recipient, including repeated visits. Also, a short subsequent questionnaire was sent to a representative sample of the intervention population (n=828) to account for intervention interest and impact perception. There was a 100% sent-out success rate. Between 50-63% of the recipients accessed the intervention at least once in every intervention trail, with slight differences between interventions and a modestly decreasing interest from one intervention session to the other. Recipients reported an overall 64% recall rate with intervention 1 at a considerable distance from all the other messages (with a 74% recall rate). In terms of usefulness, intervention 2b was highest rated (47%) followed in order by 2a, 3, and 1. 5% of the beneficiaries declare to have changed their consumption behavior because of the interventions, most of them being concentrated in the "individual benefit intervention" group 1 (7%) and the least in the group "collective information intervention" 2b. 90% of those enquired declare to monitor consumption closely. Most respondents invoke monetary stressors as determinants of energy consumption reduction, with those related to context and price (price evolution, for instance) being more powerful than self-motivation or global warming.

The performance of online interventions was assessed in relation to the control group and household energy consumption during the same period of the previous two years (2020 and 2021). The central idea was to select the best-performing intervention and to replicate it in an upscaled singular in-bill experiment on customers that use exclusively paper billing (n=2.821.124), to observe impact in a large-scale offline setting.

Based on the company management decision given the administrative load, and market opportunity, the intervention had been firmly scheduled for September 2022. The decision triggered at least two methodological challenges. First, the logistics of the intervention (printing and related subcontracting activities) required making a fast decision on what was the best-performing online intervention to be replicated at a large scale. This restricted our decision to behavioral changes immediately observable after the first round of experiments, rendering intervention 1 as the most likely candidate with an immediate consumption reduction of 2,52

percentual points below that of the control group, followed by 2b "collective information" (-2.41), 2a "individual information" (1.27 relative consumption increase) and 3 "altruism and social norm" (0.82 relative consumption increase). The decision was validated in correlation with the survey results and upscaling was approved on this basis. An overall assessment at the end of the implementation period, however, revealed a higher and statistically significant effect of intervention 2b at the expense of the others. Intervention 1 resulted in a statistically insignificant increase. The analysis is detailed below.

At the end of the intervention period, we assessed intervention impact by way of a two-way fixed effects model, where the dependent variable is the natural log of the monthly household electricity consumption:

$$\log(\text{consumption})_{it} = \beta_1 \cdot \text{treatment1}_{it} + \beta_2 \cdot \text{treatment21}_{it} + \beta_4 \cdot \text{treatment22}_{it} + \beta_3 \cdot \text{treatment3}_{it} + \alpha_i + \lambda_t + \varepsilon_{it}\beta_2$$

The variable treatment 1 is a dummy variable that equals one for households that received intervention 1 during and after the intervention period. Respectively, treatment 2.1, treatment 2.2, and treatment 3, indicate intervention 2.1, 2.2, or 3 during and after the intervention period. The α_i are the household-specific intercepts, the λ_t are the time-specific intercepts.

Table A. Romania quasi-experimental survey results

Dependent variable:	
Consumption log	
Treatment 1	0.003
(0.003)	
Treatment 2.1	−0.011***
(0.003)	
Treatment 2.2	−0.019***
(0.004)	

Treatment 3	−0.006∗
(0.003)	
Observations 1,002,290	
Note: ∗p<0.1; ∗∗p<0.05; ∗∗∗p<0.01	

The results of the regression as shown in Table A display, on average, an increase of electricity consumption after the interventions in experimental group 1 by about 0.3%. In experimental group 3 the treatment decreases the electricity consumption by about 0.6%. Both are not statistically significant. We observed that "individual framing information" as sent to experimental group 2.1 results in a decreased electricity consumption of about 1.1% and "collective framing information" results in a decreased electricity consumption of about 1.9% compared to the control group.

Second, several challenges associated with unexpected market events related to COVID-19 and the war in Ukraine triggered at least 5 major governmental decisions over the entire experimental period, some of which resulted in important price and billing changes between May and the end of September 2022. These challenges could not have been avoided, they need to be considered but are difficult to account for or be filtered out, for that matter, from the interventions.

Figure A shows the logarithm of the mean electricity consumption across all online customers. Constant changes in legislation between November 2021 and December 2022 significantly impacted energy suppliers, leading to prolonged periods of non-issuance of invoices. Consequently, this situation resulted in invoicing errors, which were subsequently rectified through regularizations. These irregularities contribute to the observed unusual peaks in the plot of electricity consumption.

Figure A: Customers with online account: Mean monthly electricity consumption (log)

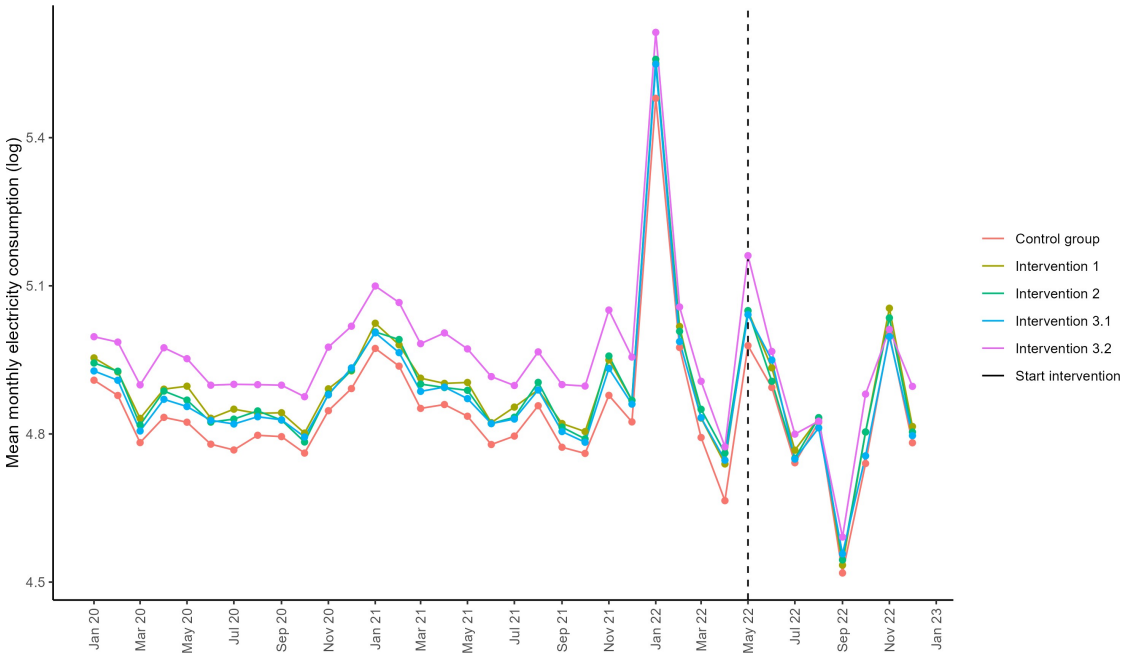
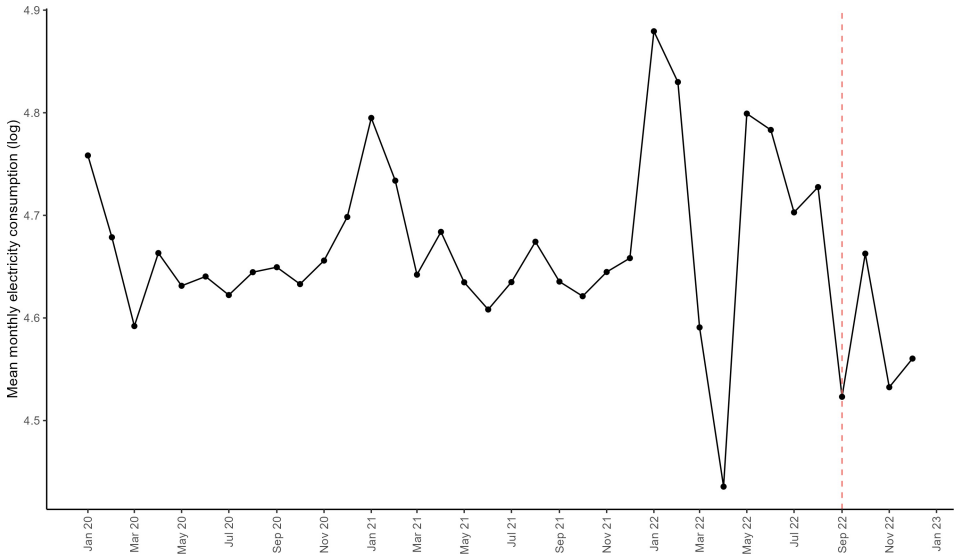


Figure B below shows the logarithm of the mean electricity consumption across offline customers



An additional methodological challenge is related to the implementation of the so-called "offline intervention": the practical difficulty of establishing an intervention control group due to high additional costs, complicated logistics, and time limitations. The immediate decision

was to amend the RCT methodology by assessing the impact in relation to consumption in the 3 immediate proximate months (October, November and December), given contextual resemblance (regulatory and climate), and to the same periods from the previous two years (2020 and 2021). This trigger additional inconsistencies given the overall contextual situation, which will be described later.

The intervention on customers without an online account and who prefer more traditional means of communication with the energy provider, was launched on the 1st of September 2022 and was performed throughout the month in multiple stages depending on the billing arrangement each customer had in place. The intervention was printed on an additional piece of paper inserted in the envelope. The visual design of the intervention remained unchanged to that used in the online experiment and it was consistent with the Electrica visual identity in terms of color palette and form.

For the analysis, monthly recorded consumption data along with a few social demographics (gender, age, location, consumption interval) were harvested for the months of October, November, and December of the years 2020, 2021, 2022. After database curation, a representative sample of online customers (n=23.345) was piled for analysis.

A few useful conclusions may be drawn from the data: consumption varied on average with -2.1% over the selected period with reference to 2021 and -7% with reference to 2020, with some nuances with regional relevance or at the level of the rural/urban split. The urban reduced consumption with almost 5% over one last year, while there was an almost proportional increase in the rural household consumption (+4,4%). Female contract holders had a comparative much higher decrease to male (-5,3% vs. -0.3% over the last year), while in terms of age, only consumers above 55 decreased their consumption (by over 3%). At the same time all the other age groups increased electricity usage (+7,1% for 35-44 for instance). Low energy consumers (i.e. habitually under 100 kWh) reduced consumption even more with -7%/-12%, whereas all the other groups either had very low reductions (-1% for 301-400kWh as per 2021) or increased their consumption altogether with up to 13-14% annually for the 151-200kWh group).

The methodology employed with the circumstantial amendments required unduly limited our ability to draw definitive conclusions regarding the causal relationship between the intervention and electricity consumption behavior. This should, however, not underestimate the meaningful policy conclusions, that may be drawn from the analysis. Due to the absence of a control group

among offline customers, it was not possible to estimate a causal effect using the difference-in-differences (DiD) method. The DiD technique relies on comparing the changes in outcomes over time between a treatment group and a control group, which allows for the identification of the causal impact of an intervention. Without a control group, it becomes challenging to isolate the effects of other potential confounding variables that might influence the outcomes.

Overall, this intervention faced challenges due to unexpected market events, made ethical considerations, was well-accepted, influenced policymaking, and had moderate replicability potential, among other findings.

3. Policy Recommendations

As the context in which consumer behavior is formed fluctuates intensively, and the multiple crises lead to increased vulnerabilities, new ways of measuring the effect of various potential interventions are needed. We presented here the findings of a large quasi-experimental survey, delivered via multiple channels (i.e. online and offline) to consumers that should be regarded as a critical illustration of the methodological challenges of scaling pilot studies to the general population in times of crises. Beyond the usual data and sample validity challenges, we also found that the replicability of past studies is complicated given the occurrence of the COVID-19 pandemic or the full-scale invasion of Ukraine during our data gathering.

Our data shows that the impact is nuanced if segmented on socio-demographic categories, place of residence (region, county, rural, large urban, and small urban), and repeated intervention - some of the interventions (Intervention1) have faded after repeated deployment, whereas others have increased in effect (Intervention 3.2). Moreover, the interventions have been performed in a situation of exceptionality on the market as an energy crisis was unfolding due to multiple unexpected events (i.e. COVID-19 pandemic, full-scale invasion of Ukraine). Performing the exercise in a repeated manner would help us better account for these variations in a diversity of market contexts. The low costs associated with the deployment of the interventions are an argument in support of such repeated testing.

The national context in Romania is characterized by little cooperation between decision-makers and energy companies, whereas both sides perform complementary actions on the market. In times of overlapping crises, the energy market is one of the key areas that requires multi-stakeholder cooperation in order to advance societal resilience [20]. This can only be successfully delivered if coordinated across different levels: data collection, policy design and

implementation. There is a high polarization between relevant domestic stakeholders (i.e. energy companies, public sector, and consumers) that results from the domestic and international political discourses and actions. Better coordination between stakeholders would result in more coherent action, lower policy-making costs (i.e. parties would share information that they collect habitually, or share competencies for the public interest), better policies, inherently a more stable and predictive market, and increased trust in the market from all key players (including consumers). This is particularly important in a sector that is affected by disruptive events to such an extent. An example of such an initiative would be the creation of tripartite committees that would engage a large spectrum of concerned public institutions, private and public companies, and consumer interests in various forms of organization (e.g. NGOs, landlord associations, municipality associations, etc.). The habitual exchange of information is encouraged in such committees. Romania implements a similar model in the field of climate policy, but this does not have an energy market focus. Scientific evidence, such as the one that resulted from our quasi-experimental interventions, can become the object of a sustained exchange committee routine leading to better-designed and deployed policies that can deliver much better in both punctual (such as energy crises) and more medium and long-term scenarios (such as the just energy transition objectives).

There is generally a high resistance and absence of trust coming from the companies to share any type of data. This decreases the potential to engage evidence in decision-making effectively, and it affects intervention deployment timelines and the quality of results. The energy market is highly competitive with many benefits for the consumers, but also with large costs in terms of public interest. It could be useful to develop at the level of the EU and the Member States broad information and engagement campaigns aimed at developing a higher trust culture at the level of energy companies. This could be done by raising awareness at the level of market actors that there is mutual benefit in sharing information and coordinating action even between market competitors. Such actions should be founded on scientific evidence, the dissemination of good practices, and networking opportunities.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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