Subsidies and War Shocks: Evidence from Norway's Electricity Market*

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Abstract

This paper examines consumer responses to the 2022 European Energy Crisis, using Norway's zonal electricity market as a natural experiment. Employing a differences-in-differences approach, we show that zones more interconnected with Europe experienced an immediate additional 7–9% reduction in household consumption relative to less interconnected zones following the price shock. We then apply a sharp regression discontinuity design to assess consumer reactions to a government subsidy scheme. Paradoxically, households just above the subsidy threshold reduced consumption more than those just below it. This pattern suggests that consumers had adapted to the new high-price environment and viewed the subsidy as temporary, rather than responding to the immediate price relief.

JEL codes: L51, Q41, Q48, H31

Keywords: consumer behavior, electricity markets, household consumption, war shocks, subsidies, contracts-for-differences, government support policies.

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1 Introduction

Over the past few decades there has been a trend towards increasing interconnectivity of different electricity markets to fully take advantage of complementarities in the generation portfolio mix. This has been particularly the case in Europe although several other jurisdictions have witnessed similar changes (Gonzales et al. (2023), Hausman (2024)). However, this increased interconnectivity exposes larger conglomerates of markets to the same supply and demand shocks, thus reducing the potential benefits of a wider and more diversified market reach.[1]

The full-scale invasion of Ukraine in 2022 caused a chain of events in energy markets that is commonly referred to as the European Energy Crisis. In particular, it caused an abnormal surge in wholesale electricity prices in almost all European electricity markets.[2] This external supply shock was transmitted through the electricity network of several countries and allows us to estimate causal effects of changes in electricity prices on electricity consumption and on the reaction of consumers to government policies designed to attenuate the impact of high prices.

This paper addresses two main questions. First, to what extent did the shock from the full-invasion of Ukraine in energy markets affect electricity prices and electricity consumption in a completely different market but that is interconnected to the rest of Europe? Second, was the consumers' response to the shock nuanced by the presence of a government subsidy that aimed at compensating consumers for the higher than usual prices?

Norway offers a unique setup to answer those questions because its market is segmented by zones −zonal pricing− and their respective levels of interconnectivity to the rest of Europe largely differ, providing a control-treatment environment within the *same* market. This addresses potential concerns regarding heterogeneous preferences. We use high-frequency data on electricity consumption covering all end-users connected to the grid, wholesale prices, and weather conditions for Norway's five bidding zones over the period January 2021 to

[1] Joskow and Tirole (2005), LaRiviere and Lyu (2022), and Lamp and Samano (2023) also studied problems related to interconnection in electricity markets.

[2] See ECB (2022); Euronews (2025).

December 2024. Consumers in Norway are exposed to electricity prices that reflect real-time wholesale prices, thus we concentrate on the overall effect of those shocks on households consumption of electricity.[3]

We proceed in two steps. First we estimate short-run electricity demand elasticities for residential consumption in Norway and find that demand is highly inelastic.[4] This is due to the high degree of electrification in Norway and thus the lack of energy substitutes for basic needs such as heating and common transportation needs such as electric vehicles. First, using the bidding zones that are the least connected to the rest of the European markets as control group, we estimate an average treatment on the treated (ATT) effect using both a static and a dynamic differences-in-differences approach. The results show that consumers reacted to the price shock by lowering consumption by 7 to 9% relative to the zones where the price increase was not present immediately in the month following the shock. Moreover, from the dynamic differences-in-differences model we observe a continuous decrease in consumption in the five months after the shock relative to the control zones.

Second, government subsidies were put in place in the form of one-sided subsidy-for-differences on consumption to compensate for the high price levels. This created a different control-treatment environment in which consumers can be in the treatment group when electricity prices are above the pre-established threshold (therefore, activating the subsidy) and consumers belong to the control group when the price is below that same threshold. We estimate this treatment effect using a sharp regression discontinuity design model. We find that the percentage decrease in consumption in the treated group was larger than in the control group. That is, for prices very close to the threshold, consumers in the treated group lower their consumption by more than in the control group despite the fact of the presence of the subsidy. Two hypotheses come to mind, consumers perhaps were unaware of the subsidy, or consumers are adapting to the new price regime because they know that is unclear whether the subsidy will be permanent or not. Based on anecdotal evidence from consumers in Norway, we think the most likely explanation is due to the latter.

[3]See Ahlvik et al. (2025) and Ajayi et al. (2024) for studies on other European markets.

[4]This is consistent with recent findings by Hofmann and Lindberg (2019). See Reiss and White (2005) for a general treatment of the estimation of elasticities in electricity markets.

2 Regulatory and Historical Background

For nearly a century, Norwegian consumers have benefited from comparatively low energy prices, especially when compared to other European countries that rely more heavily on energy imports. This favorable situation is primarily attributable to the country's abundant supply of both fossil and renewable energy sources. However, significant regional differences remain: electricity prices in Norway vary markedly between the north and the south, reflecting differences in supply, demand, and transmission capacity. To reflect these regional conditions, the electricity market is divided into five bidding zones (NO1–NO5), as shown in Figure 1. This zonal structure has been central to how recent price shocks were transmitted across the country. Approximately 90% of households have contracts directly indexed to the day-ahead spot price, meaning that shocks in wholesale markets are almost immediately reflected in household bills.[5].

In October 2021, a sharp increase in wholesale electricity prices marked the beginning of an unprecedented price shock, which was further amplified in February–March 2022 following Russia's invasion of Ukraine and the resulting turbulence in European energy markets. The southern zones: NO1 (East), NO2 (South), and NO5 (West) were hit hardest. Their integration with continental markets through interconnectors to Denmark, Germany, and the United Kingdom meant that domestic prices closely tracked the high levels abroad. At the same time, low water levels in southern hydropower reservoirs constrained supply, further fueling the surge.

By contrast, zones NO3 (Central) and NO4 (North) were largely shielded from the crisis. Their reservoirs were relatively well supplied, and crucially, these zones are not directly connected to continental Europe. As a result, their wholesale prices often remained a fraction of those in the South, sometimes close to zero, producing a 'two-tier' electricity market within Norway. In the second quarter of 2025, the average spot price in NO4 (Northern Norway) was about 5 øre/kWh, compared with 14 øre/kWh in NO3 (Central Norway). By contrast, average spot prices reached 68 and 62 øre/kWh in the high-price areas of NO1, NO2, and

[5]See SSB (2025); and NVE–RME: Norway's smart-meter journey.

Figure 1: Norway's electricity bidding zones (NO1–NO5).

Notes: The electricity market in Norway is divided in five interconnected bidding zones. Zones 3 and 4 were largely shielded from the energy crisis. Zones 1, 2, and 5 were impacted by electricity price increases.

NO5 (Southwest and Southeast Norway), respectively. In other words, wholesale electricity was 12 to 14 times more expensive in Southern Norway than in Northern Norway and this price gap was even wider during 2022, when prices in the south peaked at exceptionally high levels.[6] As a result, Norwegian households mainly in the south have experienced high electricity bills, prompting many to become more price-aware in their daily consumption.

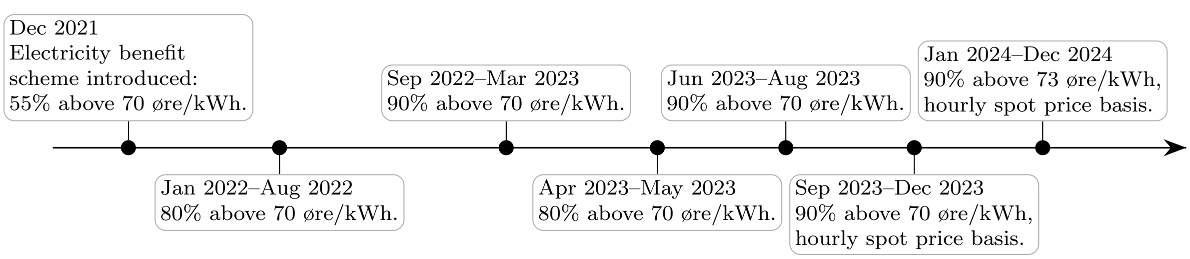
These extreme regional disparities prompted an unusual government response. In December 2021, the government introduced a subsidy program that compensated households for

[6]See SSB (2023).

the share of the electricity price above a fixed threshold (initially NOK 0.70 per kWh), later expanded in generosity and duration.

As these policy adjustments unfolded in step with market conditions, the government's support evolved in discrete stages, initial 55% coverage above the threshold (December 2021), expansion to 80% and then 90%, a shift from monthly to hourly settlement in September 2023, and higher thresholds in 2024–2025. The sequence is summarized in Figure 2. These extreme regional disparities prompted an unusual government response. In December 2021, the Norwegian government introduced a subsidy program intended to offset the worst price increases in the most affected regions. The policy compensated consumers for a portion of their electricity bill exceeding a fixed threshold initially set at NOK 0.70 per kWh. Over time, the program was expanded in terms of both generosity and duration. Compensation rates increased, and eligibility was extended to include farmers and housing cooperatives. As these policy adjustments unfolded in step with market conditions, the government's support evolved in discrete stages initial 55% coverage above the threshold (December 2021), expansion to 80% and then 90%, a shift from monthly to hourly settlement in September 2023, and higher thresholds in 2024–2025. The sequence is summarized in Figure 2.

Figure 2: Timeline of household electricity subsidy mechanisms in Norway, 2021–2024.



Notes: While the percentage amount covered by the subsidy fluctuated over time, the threshold above which the subsidy is active remained constant at 0.70 NOK / kWh throughout from the beginning of the policy until January 2024 when it was increased to 0.73 NOK / kWh.

The introduction of electricity subsidies was a significant policy change in Norway's energy market. Although the program was initially intended as a temporary relief measure, it quickly became one of the largest fiscal responses to the energy crisis in Europe. The program's rapid expansion reflected the severity of regional disparities and the government's efforts to protect households from unprecedented price shocks.

However, the program also raised important questions about efficiency and distribution. By compensating consumers above a fixed threshold, the program reduced incentives to reduce demand during periods of scarcity. At the same time, since only certain regions experienced extremely high prices, the subsidies reinforced the two-tier market structure. Understanding how households responded to these subsidies, whether by reducing, maintaining, or increasing their electricity consumption provides crucial insights into the interplay between market prices and government intervention.

3 Data

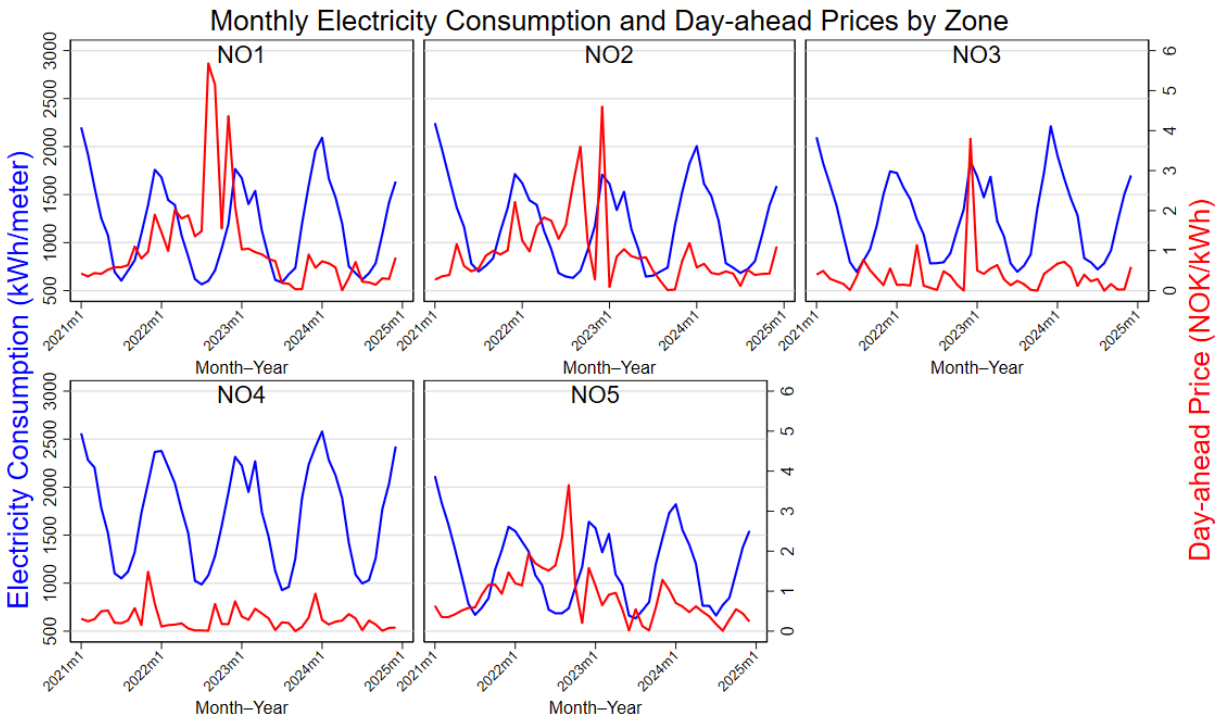
We use high-frequency data on electricity consumption, wholesale prices, and weather conditions for Norway's five bidding zones (NO1–NO5) over the period January 2021 to December 2024. Household consumption is measured at the hourly level and obtained from Elhub[7], the national data hub for electricity metering in Norway. These data cover all end-users connected to the grid and provide a comprehensive picture of residential demand patterns across zones.

Hourly day-ahead wholesale prices are sourced from Nord Pool, the Nordic electricity exchange, which operates the common power market for Norway and neighboring countries. These prices are set one day in advance based on market clearing and vary by bidding zone, reflecting both local hydrological conditions and interconnection constraints.

Figure 3 illustrates the evolution of monthly average electricity consumption and day-ahead prices across the five zones. Consumption (blue) follows a strong seasonal pattern, peaking in winter months and declining during summer, consistent with heating demand. Prices (red) show much greater regional variation: zones NO1, NO2, and NO5 in the South experienced pronounced price spikes during the 2021–2023 crisis period, whereas NO3 (Central) and NO4 (North) remained largely insulated, with wholesale prices staying relatively low and stable. The observed divergence underscores the importance of analyzing the crisis at the zonal level rather than aggregating to the national average.

[7] Elhub.no

Figure 3: Monthly electricity consumption and average day-ahead prices by zone



Notes: The left-hand y-axis shows the average monthly electricity consumption per meter in each bidding zone (kWh), while the right-hand y-axis displays the average hourly day-ahead price per month (NOK/kWh). The graph presents these two variables over time for each bidding zone (NO1–NO5).

It is also important to control for other external factors that may influence electricity consumption independently of price. For example, temperature plays a key role as people naturally use more electricity when it's cold. The hourly temperature records were obtained from the Norwegian Meteorological Institute. Given the inaccessibility of more granular spatial coverage, we select one major city per bidding zone: Oslo (NO1), Stavanger (NO2), Trondheim (NO3), Tromsø(NO4) and Bergen (NO5) to approximate the weather conditions at the zone level.

Table 1 summarizes descriptive statistics of key variables by zones. The average hourly electricity consumption per meter exhibits a range from approximately 1.6 kWh in Zones NO1, NO2, and NO5 to 2.4 kWh in Zone NO4, thereby indicating a higher baseline demand in the northern regions. Electricity prices also vary substantially across zones. For instance, Zones NO1, NO2, and NO5 face average prices close to 0.9 NOK/kWh, while Zones NO3 and NO4 exhibit considerably lower average prices. Thus, the observed price variations can be attributed to the presence of regional differences in market conditions. Temperature variation is also substantial, with mean values ranging from 3.9°C in Zone NO4 to 8.6°C in Zone NO2, and extreme minimums below -20°C in some zones. Consistent with these patterns, heating degree days (HDD) are highest in Zones NO3 and NO4, while cooling degree days (CDD) remain low across all zones, thereby indicating that heating demand is the predominant factor influencing electricity consumption in Norway during the examined sample.

4 The Effect on Consumption

To estimate the impact of rising electricity prices on household electricity demand, we begin with a simple Difference-in-Differences (DiD) specification. The empirical model is given by:

$$\log Y_{zt} = \beta_0 + \beta_1 \text{Post}_{zt} + \beta_2 \text{Treated}_{zt} + \beta_3 (\text{Post}_{zt} \times \text{Treated}_{zt}) + \mathbf{X}_{zt} \boldsymbol{\beta} + \alpha_z + \gamma_t + \varepsilon_{zt}, \quad (1)$$

where Y_{zt} denotes the average electricity consumption per household in zone z and month t. Post_{zt} is an indicator equal to one for periods after March 2022, marking the onset of the price shock, while Treated_{zt} is equal to one for zones exposed to the price increase (Zones 1, 2, and 5). The interaction term $(\text{Post}_{zt} \times \text{Treated}_{zt})$ captures the DiD estimate of the treatment effect. $\mathbf{X}_{zt}$ is a vector of weather-related controls, α_z are zone fixed effects, γ_t are month-year fixed effects, and ε_{zt} is the error term.

4.1 Using March 2022 as the treated month

The credibility of the difference-in-difference framework relies on the assumption that treated and control zones would have followed parallel trends in the absence of treatment. To assess this, Figure A.1 plots the mean log consumption ... The figure shows broadly similar trajectories prior to the onset of the price shock, lending support to the assumption.

While visual inspection suggests that the parallel trends assumption is broadly satisfied, the analysis moves forward to the estimation of treatment effects. Table 2 reports the baseline

Table 1: Descriptive Statistics by Zone: Mean, SD, Min, Max, N

Variable	Mean	SD	Min	Max	N
Zone NO1					
Consumption (kWh/meter)	1.602	0.689	0.527	3.889	34939
Electricity price (Nok)	0.923	0.853	0.000	7.766	34939
Temperature (Celsius)	7.432	8.651	-22.900	31.000	34939
HDD	10.048	7.920	0.000	39.900	34939
CDD	0.481	1.528	0.000	14.000	34939
Zone NO2					
Consumption (kWh)	1.620	0.645	0.581	3.795	34940
Electricity price	0.944	0.843	0.000	8.983	34940
Temperature	8.625	7.681	-14.200	29.700	34940
HDD	8.813	7.034	0.000	31.200	34940
CDD	0.438	1.346	0.000	12.700	34940
Zone NO3					
Consumption (kWh)	1.736	0.636	0.622	3.717	34940
Electricity price	0.371	0.413	0.000	5.728	34940
Temperature	6.865	7.727	-17.500	30.400	34940
HDD	10.396	7.286	0.000	34.500	34940
CDD	0.261	1.090	0.000	13.400	34940
Zone NO4					
Consumption (kWh)	2.365	0.775	0.780	4.376	34939
Electricity price	0.280	0.292	0.000	4.901	34939
Temperature	3.916	7.277	-13.900	30.000	34934
HDD	13.218	6.976	0.000	30.900	34939
CDD	0.136	0.844	0.000	13.000	34939
Zone NO5					
Consumption (kWh)	1.592	0.591	0.560	3.624	34939
Electricity price	0.920	0.846	0.000	7.767	34939
Temperature	7.819	6.601	-11.400	29.600	34939
HDD	9.420	6.158	0.000	28.400	34939
CDD	0.240	1.065	0.000	12.600	34939

difference-in-differences results, using March 2022 as the start of the treatment period. Across specifications, the coefficient on the interaction term ($Treated \times Post$) is negative and highly significant, indicating a reduction in consumption in treated zones following the occurrence of the price shock. The estimated effect is approximately 7 percent in most specifications, with the magnitude remaining stable after the inclusion of fixed effects and controls.

The results also highlight the importance of including weather controls. In column (4), the inclusion of temperature, heating degree days, and cooling degree days shows the expected signs: heating demand increases consumption, while cooling demand reduces it. The treatment effect remains robust to the inclusion of these controls, with only a modest reduction in magnitude (from –0.072 to –0.065).

The post-treatment indicator (*Post*) is positive and large in the specifications without time fixed effects, reflecting the overall increase in consumption over time that is absorbed once month-year fixed effects are included. Similarly, the treated zone indicator (*Treated*) is negative but not robustly significant, indicating some baseline differences in consumption levels across zones.

4.2 Using October 2022 as the treated month

Given that the first substantial price spikes occurred already in October 2021, prior to the outbreak of the war in Ukraine (see Figure 3), we also estimate the model using October 2021 as the start of the treatment period. The results, reported in Table 3, show that the interaction term (*Treated* × *Post*) is negative and statistically significant across all specifications, with estimates between –0.085 and –0.079. This implies an average reduction in electricity consumption of around 8 percent in the treated zones relative to the controls after October 2021.

The effect is slightly larger than the 6–7 percent reduction estimated when March 2022 is used as the treatment period, suggesting that households in the treated zones responded to elevated prices already during the autumn of 2021. The results remain robust when including zone and month-year fixed effects, as well as when controlling for weather conditions in column (4). As expected, the coefficients on heating and cooling degree days are positive and negative, respectively, reflecting the strong influence of seasonal temperature variation on electricity use. Table 3 presents the regression results using October as the treated month.

Table 2: Regression Results: Monthly Data

	(1)	(2)	(3)	(4)
Treated × Post	-0.072***	-0.072***	-0.072***	-0.065***
	(0.007)	(0.008)	(0.007)	(0.004)
Post	2.461***		2.461***	
	(0.001)		(0.001)	
Treated	-0.199	-0.199		
	(0.125)	(0.140)		
Temperature				1.086***
				(0.096)
Temperature^2				0.00006
				(0.0003)
Heating Degree Days				1.090***
				(0.100)
Cooling Degree Days				-1.119***
				(0.119)
Intercept	7.320***	9.063***	7.200***	-9.552***
	(0.125)	(0.140)	(0.003)	(1.698)
Zone FE	No	No	Yes	Yes
Month-Year FE	No	Yes	No	Yes
Adj.R^2	0.122	0.998	0.111	0.999
N	240	240	240	240

Standard errors in parentheses.

Dependent variable: Log of monthly average consumption per meter.

Treatment starts in March 2022. Zones 1, 2, and 5 are treated; Zones 3 and 4 are controls.

Std. errors clustered at zone level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Regression Results: Monthly Data

	(1)	(2)	(3)	(4)
Treated × Post	-0.085***	-0.085***	-0.085***	-0.079**
	(0.015)	(0.016)	(0.014)	(0.019)
Post	2.277***		2.277***	
	(0.005)		(0.005)	
Treated	-0.181	-0.181		
	(0.123)	(0.137)		
Temperature				0.977***
				(0.154)
Temperature^2				0.000002
				(0.0004)
Heating Degree Days				0.980***
				(0.159)
Cooling Degree Days				-1.011***
				(0.181)
Intercept	7.213***	9.063***	7.105***	-7.684**
	(0.122)	(0.140)	(0.007)	(2.695)
Zone FE	No	No	Yes	Yes
Month-Year FE	No	Yes	No	Yes
Adj.R^2	0.072	0.998	0.061	0.999
N	240	240	240	240

Standard errors in parentheses.

Dependent variable: Log of monthly average consumption per household.

Treatment starts in October 2021. Zones 1, 2, and 5 are treated; Zones 3 and 4 are controls.

Std. errors clustered at zone level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.3 Additional robustness checks: alternative control groups and treatment timing

To further assess the robustness of the results, we test whether the results are sensitive to the choice of control group by re-estimating the Difference-in-Differences model using each control zone separately rather than pooling Zones 3 and 4.

Table A.2 reports the results when Zone 4 alone is used as the control group, while Table A.1 shows the corresponding results using Zone 3 only. In both cases, the dependent variable is the log of electricity consumption per household. The treatment effect remains negative and statistically significant, confirming that the observed demand reduction in treated zones is not driven by the composition of the control group. The magnitude of the effect is somewhat larger when Zone 4 (the northern zone with higher electricity consumption and colder climate) is used as the control, while Zone 3 yields smaller estimates. This outcome is not surprising, as demonstrated in Figure 3, Zone 4 experienced little or no price increase during the critical period of 2022–2023, whereas prices rose sharply in the treated zones, making Zone 4 a more comparable benchmark for identifying demand responses.

We also replicate the same exercise using only data up to August 2022, before the subsidy coverage was increased from 80% to 90%. The results, presented in Table A.5 and Table A.4, are highly consistent with the baseline findings. The treatment effect remains negative and statistically significant across both specifications, further reinforcing the robustness of our conclusions.

Finally, we examine whether the results hold when moving the treatment onset back to October 2021, when the first sharp price increases occurred prior to the outbreak of the war in Ukraine. Restricting the data to the period before the subsidy coverage changed to 90 percent, Table A.6 shows that the treatment effect is again negative and statistically significant, with an estimated reduction in electricity consumption of roughly 8–9 percent in the treated zones relative to controls.

The reliability of the findings is reinforced by the consistency of the results across these alternative specifications. Households in treated zones exhibited a systematic reduction in electricity consumption in response to rising prices, irrespective of the definition of the treatment month as October 2021 or March 2022, the definition of the control group as narrowly (Zone 3 or Zone 4) or more broadly (pooled controls), and the restriction of the sample to the pre-subsidy expansion period ending in August 2022 or its extension over the full horizon.

4.4 Dynamic effects

We constructed a series of time dummies indicating the number of months before and after the treatment. These are interacted with the treatment indicator to estimate the monthly impact relative to the baseline month (February 2022), which is omitted. The regression controls for zone and month-year fixed effects and clusters standard errors at the zone level.

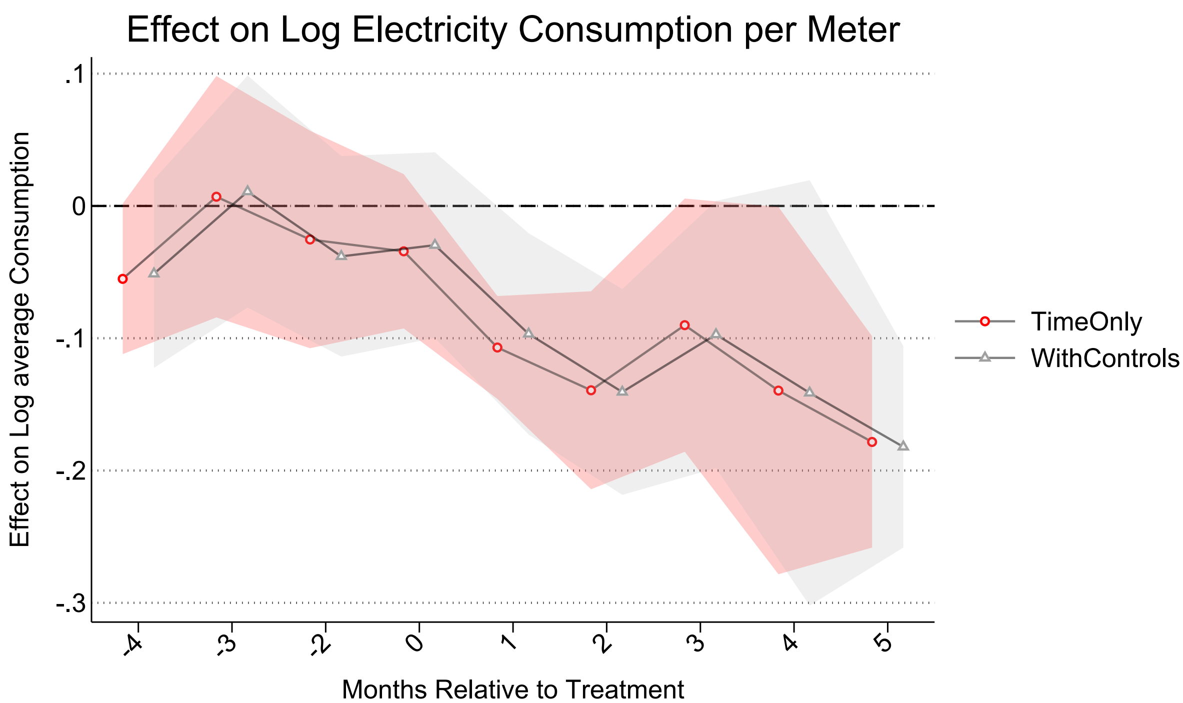
$$\log Y_{zt} = \sum_{\substack{k \neq -1 \\ k=-m}}^{M} \beta_k (\text{Treated}_{zt} \times \text{I}_{tk}) + \mathbf{X}_{zt}\boldsymbol{\beta} + \alpha_z + \gamma_t + \varepsilon_{zt}, \tag{2}$$

where I_{tk} is a binary variable equal to 1 if distance between event and time t is k, 0 otherwise.

Figure A.2 shows the event-study coefficients using the monthly average consumption as the dependent variable. The vertical line at period 0 marks the first month of treatment (March 2022). It includes all control variables.

In Figure 4 we show the results for the same specification but using data throughout August 2022 and generate the event study plot to examine the treatment dynamics within this period at monthly and weekly level. The results from the two samples give the same results, with a slightly lower statistical significance for the third month after the treatment date when using the larger dataset.

Figure 4: Event Study: Dynamic Treatment Effects



Notes: Each dot represents the effect on log average consumption for each month relative to the treatment date, data up to August 2022. Shaded areas represent the 90% confidence intervals.

5 The Role of Subsidies

The electricity subsidy scheme was implemented in phases, each characterized by different coverage rates and price thresholds. In general, the subsidy *per kWh* at time t can be described as

$$\text{subsidy}_t = K \times \max\{0, p_t - p^*\},$$

where p_t is the electricity price at time t and p^* is the price threshold above which the subsidy is activated. The price to compute the subsidy, p_t, has been defined slightly differently at different phases of the policy as explained below. Thus, the difference $p_t - p^*$, when positive, determines the subsidy spread. K is the coverage rate and is a constant between 0 and 1 that represents the amount of that spread that is reimbursed to consumers. As explained below, since December 2021, p^* has taken the values 0.70 and 0.73 at different points in time, and

K has been set at 0.55, 0.80, and 0.90 at different points in time.

Table 4 summarizes the subsidy design across the six phases. Up to Phase 4 (January 2022–August 2023), the subsidy was calculated using the monthly average electricity price. Beginning with Phase 5 (September 2023), the calculation shifted to the hourly spot price, which continued into Phase 6 (January–December 2024). Yet, the coverage rate increased from 55 percent in December 2021 (Phase 1) to 80 percent in early 2022 (Phase 2), and further to 90 percent between September 2022 and March 2023 (Phase 3). Coverage was temporarily reduced to 80 percent during April–May 2023 (Phase 4), before returning to 90 percent in June–December 2023 (Phase 5). In January 2024 (Phase 6), coverage remained at 90 percent, though the price threshold was slightly raised from 0.70 NOK/kWh to 0.73 NOK/kWh.

Table 4: Electricity Subsidy Phases

Phase	Period	Coverage and Threshold	Basis
1	Dec 2021	55% coverage above 0.70 NOK/kWh	Monthly avg. price
2	Jan–Aug 2022	80% coverage above 0.70 NOK/kWh	Monthly avg. price
3	Sep 2022–Mar 2023	90% coverage above 0.70 NOK/kWh	Monthly avg. price
4	Apr–May 2023	80% coverage above 0.70 NOK/kWh	Monthly avg. price
5	Jun–Dec 2023	90% coverage above 0.70 NOK/kWh	Hourly spot price
6	Jan–Dec 2024	90% coverage above 0.73 NOK/kWh	Hourly spot price

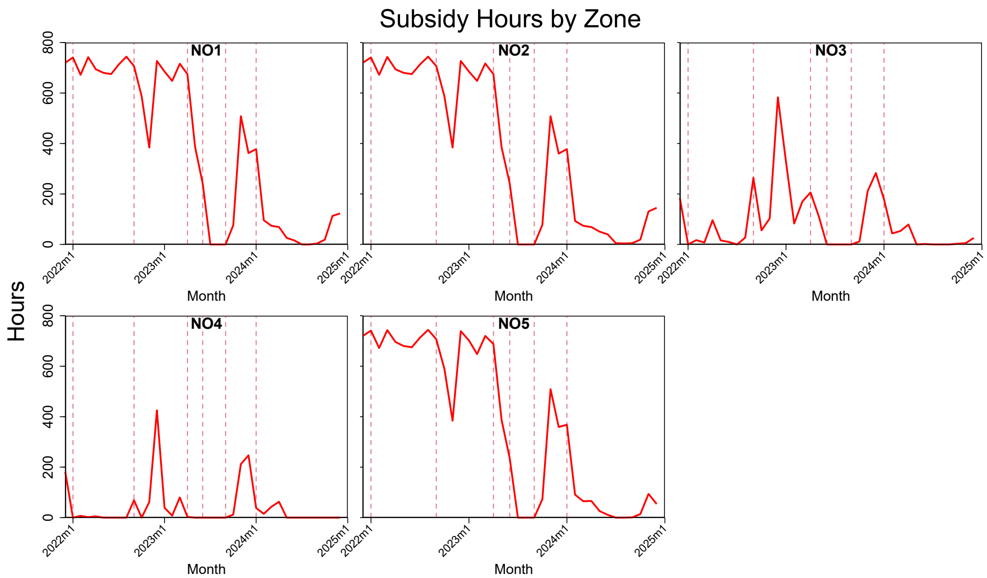
Notes: The subsidy threshold was constant throughout most of the sample period and was only slightly increased in January 2024. The calculation basis shifted from monthly average electricity prices (Phases 1–4) to hourly spot prices (Phases 5–6).

5.1 Four facts about the electricity subsidies in Norway

To illustrate how these rules translated into observable market outcomes, we present several descriptive figures.

The subsidy was active almost all the time right after the shock. Figure 5 shows the frequency of subsidy hours per month in each zone, capturing the intensity of the scheme across time and zone.

Figure 5: Frequency of subsidy activity

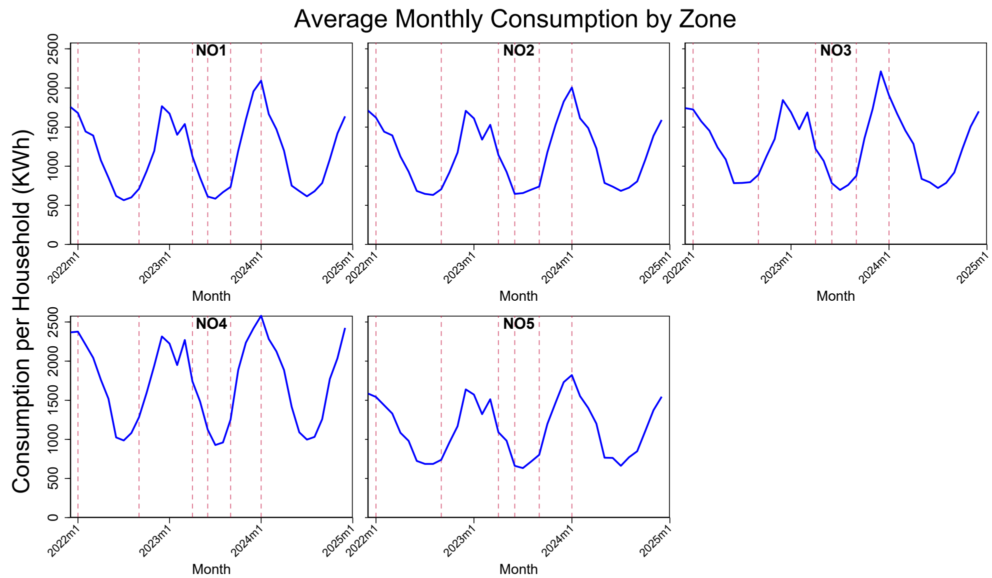


Notes: The figure shows the number of hours per month in which the subsidy was activated, by electricity zone. Treated zones (1, 2, and 5) experienced frequent subsidy hours due to higher wholesale prices, while control zones (3 and 4) show limited subsidy activity. Vertical lines reflect changes in the subsidy design (see Table 4).

Subsidy activity increased sharply from late 2021 onward, consistent with the introduction of the scheme, and remained concentrated in Zones 1, 2, and 5. In contrast, Zones 3 and 4 experienced limited subsidy exposure, reflecting lower average prices. The figure also illustrates the drop in subsidy hours during 2023 before a renewed increase in early 2024, in line with the price patterns observed in Figure 3.

Extent of subsidy exposure does not determine consumption levels. Figure 6 shows the average monthly electricity consumption per household across zones. Consumption exhibits a pronounced seasonal cycle, with peaks during the winter months and troughs in the summer. Zone 4 stands out with consistently higher consumption, reflecting its location in northern Norway where colder climatic conditions and longer winters substantially increase heating demand. These high levels of consumption occur even though a small number of hours per month were eligible for the subsidy (Figure 3).

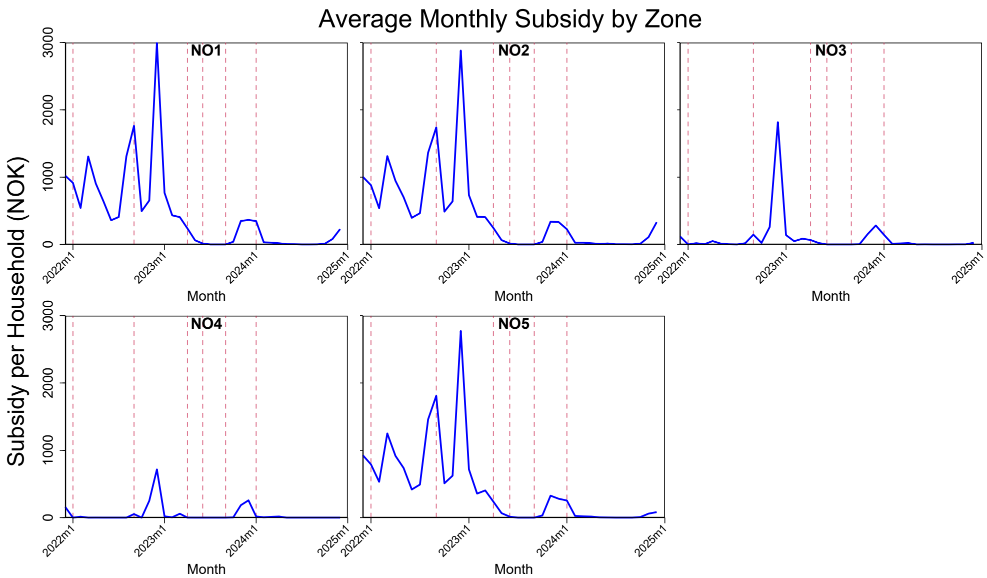
Figure 6: Electricity consumption



Notes: Vertical lines indicate changes in the subsidy design (see Table 4).

Subsidy amounts were negligible after mid-2023. Figure 7 shows the average monthly subsidy by zone. Subsidy expenditures track both consumption levels and wholesale price volatility, with pronounced peaks during the winter of 2022–2023 when subsidies exceeded 2,500 NOK per household on average in the treated zones. Conversely, Zones 3 and 4, which experienced lower prices, received significantly less compensation. The heterogeneity in the subsidy compensation highlights the variation in treatment intensity across zones. Despite that hundreds of hours per month were eligible for the subsidy after mid-2023 (Figure 5), the monthly average subsidy amounts were largely negligible.

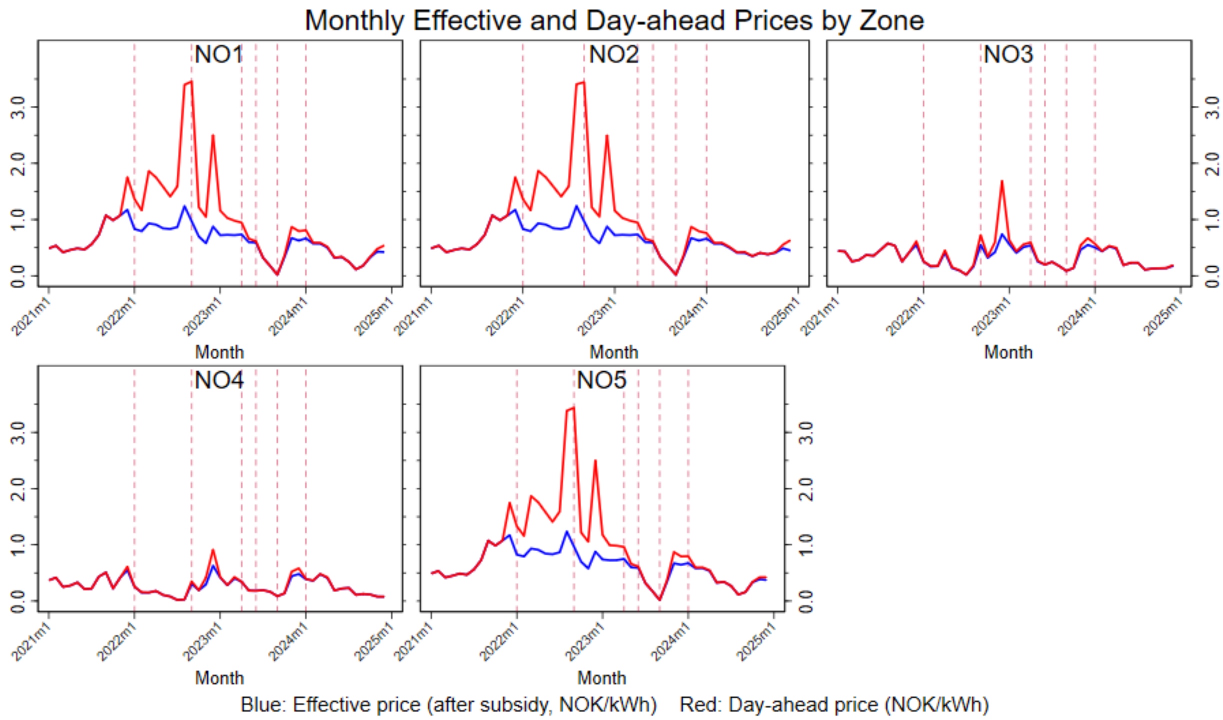
Figure 7: Subsidy expenditures



Notes: The figure shows average monthly subsidy compensation on electricity bills per household (NOK) across zones. Vertical dashed lines indicate changes in the subsidy design (see Table 4).

Spikes in prices were present only in the treated zones. Figure 8 shows the relationship between day-ahead market prices and the effective consumer prices after subsidies. The substantial gap between the two series highlights the extent to which subsidies shielded households from significant price increases across zones, particularly during the winter season of 2022–2023. The dashed vertical lines indicate the points at which the subsidy design underwent significant modifications, most notably the transition from a monthly average to an hourly spot calculation in September 2023.

Figure 8: Day-ahead market price vs. effective consumer price after the electricity subsidy



Notes: Dashed vertical lines mark changes in the subsidy design (Jan 2022, Sep 2022, Apr 2023, Jun 2023, Sep 2023, Jan 2024).

5.2 A regression discontinuity design analysis

Based on this descriptive evidence, we implemented a sharp regression discontinuity design (RDD) to study the causal effect of the timing of the subsidy on the households' electricity consumption.[8] The identification strategy operates under the assumption that potential outcomes evolve smoothly around the cutoff −in this case the threshold price for the subsidy−, such that any discontinuous jump in consumption can be attributed to the introduction of the subsidy. To address potential biases arising from polynomial specification or bandwidth choice, the analysis follows best practices by reporting both bias-corrected and robust estimates (Calonico et al., 2014).

In more precise terms, we estimate an RDD model where the dependent variable is the log of electricity consumption in zone z at time t, and the running variable is the price (NOK

[8]This is a sharp RDD because the threshold fully determines the treatment and control groups, as opposed to a fuzzy RDD where the threshold determines only the probability of being treated.

/ kWh) in zone z at time t. Estimates are presented for a range of bandwidths and kernel functions, including both uniform and triangular kernels, which serve as sensitivity checks for the robustness of the results. In some specifications we also add the same control variables that we used in the previous section.

Table 5: RDD Estimates: Log Monthly Consumption

		All phases (1–6)		90% coverage phases	
Method	Bandwidth	(1)	(2)	(3)	(4)
Panel A: Triangular kernel					
Bias-corrected	0.88	-0.699**	-0.923***	-1.100	-0.820
		(0.349)	(0.312)	(0.682)	(0.562)
Robust	0.88	-0.699	-0.923**	-1.100	-0.820
		(0.517)	(0.407)	(1.068)	(0.818)
Panel B: Uniform kernel					
Bias-corrected	0.77	-1.027***	-1.089***	-1.392**	-1.100*
		(0.329)	(0.306)	(0.662)	(0.569)
Robust	0.77	-1.027**	-1.089**	-1.392	-1.100
		(0.519)	(0.437)	(1.037)	(0.827)
Bias-corrected	0.83	-1.027**	-1.198***	-1.322*	-1.174**
		(0.343)	(0.317)	(0.697)	(0.596)
Robust	0.83	-1.027	-1.198***	-1.322	-1.174
		(0.538)	(0.447)	(1.115)	(0.895)
Bias-corrected	0.68	-0.699**	-0.923***	-1.100	-0.820
		(0.349)	(0.312)	(0.682)	(0.562)
Robust	0.68	-0.699	-0.923**	-1.100	-0.820
		(0.517)	(0.407)	(1.068)	(0.818)
Bias-corrected	0.50	-1.027***	-0.195	2.149**	1.379**
		(0.329)	(0.436)	(0.835)	(0.665)
Robust	0.50	-1.027**	-0.195	2.149	1.379
		(0.519)	(0.597)	(1.429)	(1.145)

Notes: Coefficients reported with standard errors in parentheses. Dependent variable: log of monthly average consumption per meter. Columns (1)–(2) use all subsidy phases (1–6); Columns (3)–(4) use only the 90% subsidy coverage phases. Columns (2) and (4) include the same controls as in the differences-in-differences specification in section 4. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The coefficient of interest is the average treatment effect obtained as the price approaches the subsidy threshold in the limit. This is also known as the local average treatment effect (LATE) because it represents the difference between the treated and control groups effects only in the limit. The results are summarized in Table 5. We obtained a negative and statistically significant coefficient across a variety of combinations of kernel types, bandwidths, time spans, and adding or omitting control variables. The only two exceptions to that are two of the coefficients obtained when the bandwidth was set equal to 0.50, in which case the coefficient is positive. However, those two coefficients are not completely reliable results because the sample size decreases as the bandwidth decreases in those two cases.

Using the result from Panel A column 1 in Table 5, the subsidy threshold causes an immediate drop in consumption of approximately 50.3% ($= (\exp(-0.699) - 1) \times 100\%$) when electricity is priced right around the subsidy threshold. The LATE isolates the causal impact of subsidy for the specific set of quantity-price pairs right at the threshold, having already controlled for the continuous relationship between consumption and price on both sides. The coefficient should not be interpreted as the effect of the price changing by one unit. The RDD design is agnostic as of what happens to consumption when prices are far from the subsidy threshold. Therefore, despite the subsidy, consumers lower their consumption by a large amount when the price crosses this price point.

The incorporation of weather-related controls in columns (2) and (4) of Table 5 serves to mitigate potential confounding from seasonal variation in energy utilization. The findings suggest that the impact of the subsidy is unaffected even when these variables are included.

6 Conclusion

In summary, we employed a difference-in-differences approach, which yielded findings that the price shock had a significant and *immediate* impact on household consumption. Zones more interconnected with Europe (NO1, NO2, and NO5) experienced a 7% to 9% greater reduction in electricity consumption compared to the less-connected zones (NO3 and NO4) immediately following the price shock. This effect proved robust across various specifications, including different start dates for the treatment period (October 2021 and March 2022), alternative definitions of the control group, and different sample periods. Furthermore, our dynamic analysis showed a continuous decrease in consumption in the treated zones for several months following the shock, indicating a sustained behavioral response to the high-price environment.

Then we analyzed the paradoxical effect of the government's substantial subsidy program, which was designed to shield consumers from high prices. Using a sharp regression discontinuity design (RDD), we assessed household behavior around the pre-established price threshold where the subsidy became active. We find that households with prices just *above* the subsidy threshold reduced their consumption more significantly than those with prices just *below* it. Specifically, consumption dropped by approximately 50% for prices right at the threshold. This counterintuitive finding suggests that consumers did not primarily react to the immediate price relief offered by the subsidy. Instead, it indicates a forward-looking behavioral adaptation. We hypothesize that households perceived the subsidy as a temporary measure and adapted their consumption habits in anticipation of a sustained high-price regime, a view supported by anecdotal evidence. The presence of the subsidy did little to curb the incentive to conserve energy when prices were high; in fact, the price threshold itself appears to have served as a salient signal that prompted further reductions in consumption.

In summary, our research provides causal evidence of household responses to an unprecedented energy market shock. Consumers in highly exposed regions reacted swiftly by reducing demand, and government subsidies, while providing financial relief, did not dampen conservation efforts and may have even reinforced them by signaling the severity of the crisis. These findings offer crucial insights for policymakers designing support schemes during energy crises, highlighting the complex interplay between market prices, government interventions, and long-term consumer behavior adaptation.

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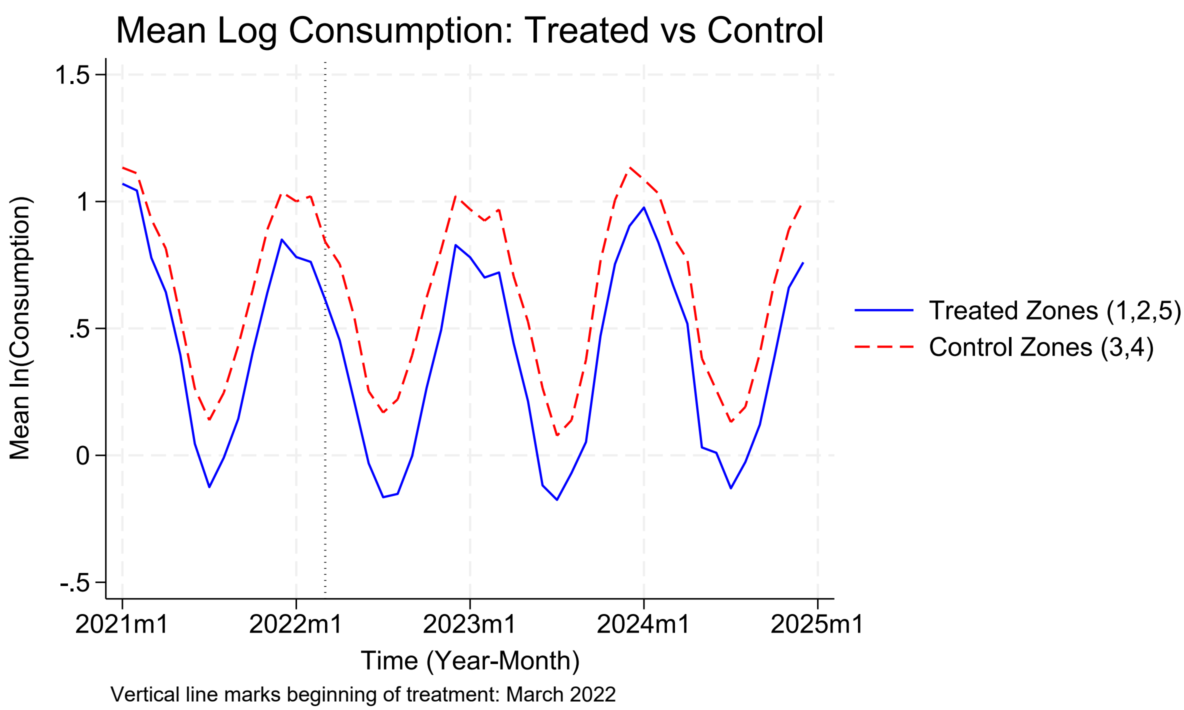
Appendix

A Additional Figures and Tables

A.1 Parallel trend test

Figure A.1 displays the monthly median electricity consumption for the treated and control groups before and after the treatment date: March 2022. The plot confirms that the trends in consumption were similar prior to the treatment period, thereby supporting the parallel trends assumption.

Figure A.1: Comparing consumption before and after treatment



Notes: Each line represents the mean log electricity consumption per meter in the treated and control zones.

In addition, we tested the parallel trends assumption using an event study framework, where February 2022 (event time -1) was omitted as the reference category. Since electricity prices began rising in October 2021 and the 55% subsidy was introduced in December 2021, we tested for differential consumption trends before the treatment month March 2022. When testing the months from June 2021 to January 2022 (event time -9 to -2), we find statistically significant differences between treated and control zones ($F(3, 4) = 6.77$, $p = 0.048$), likely reflecting early behavioral responses to rising prices. However, when restricting the test to the period June 2021 to October 2021 (event time -9 to -5), we fail to reject the null hypothesis ($F(3, 4) = 2.34$, $p = 0.215$). So, the treated and control zones followed similar trends during that period.

A.2 Robustness checks: Restricting the control group to one zone only

In the main results we used zones 3 and 4 as a single control group. To assess whether the choice of one of those zones separately may have an influence on our results, Table A.1 shows the results from the specification Equation 1 using only zone 3 as control and Table A.2 using only zone 4 as control. In both cases, the main coefficient of interest remains largely unchanged and statistically significant relative to our main specification (Table 2), which uses both zones as controls. This confirms that the choice of zones 3 or 4 as controls is irrelevant.

A.3 Keeping data up to August 2022: before the subsidy coverage changed from 80 to 90%

Table A.3 reports results similar to Table 2 but restricting the sample up to August 2022, which is the last month before the subsidy coverage changed from 80 to 90%. This addresses the potential concern that consumers' behavior changed once they were offered a slightly more generous subsidy. However, using this restricted sample captures a slightly stronger reaction of consumers to the price shock (coefficients of -0.097 and -0.110) but not strongly significant across the different specifications.

Next, to assess simultaneously the influence of the choice of the control zone and the change in the amount of the subsidy, Table A.4 and Table A.5 show the results from Equation 1 using data up to August 2022 and using as control group only zone 3 or zone 4, respectively. In both cases, the coefficient remains stable and statistically significant at the level of the previous paragraph where we used as control group zones 3 and 4 together.

Table A.1: Regression Results: Monthly Data

	(1)	(2)	(3)	(4)
Treated × Post	-0.070	-0.070***	-0.070	-0.061***
	(1.048)	(0.017)	(1.053)	(0.007)
Post	2.459***		2.459***	
	(0.907)		(0.912)	
Treated	-0.042	-0.042***		
	(0.882)	(0.015)		
Temperature				-0.045
				(0.047)
Temperature^2				0.0004
				(0.0004)
Heating Degree Days				-0.036
				(0.041)
Cooling Degree Days				0
				(.)
Intercept	7.163***	8.905***	7.131***	9.519***
	(0.764)	(0.007)	(0.384)	(0.712)
Zone FE	No	No	Yes	Yes
Month-Year FE	No	Yes	No	Yes
Adj.R^2	0.117	0.999	0.107	0.999
N	192	192	192	192

Standard errors in parentheses

Dependent variable: Log of monthly average consumption per household.

Treatment starts in March 2022. Zones 1, 2, and 5 are treated; Only Zone 3 serves as the control group.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.2: Regression Results: Monthly Data

	(1)	(2)	(3)	(4)
Treated × Post	-0.074	-0.074***	-0.074	-0.069***
	(1.049)	(0.021)	(1.055)	(0.004)
Post	2.463***		2.463***	
	(0.909)		(0.913)	
Treated	-0.356	-0.356***		
	(0.883)	(0.018)		
Temperature				1.056***
				(0.154)
Temperature^2				-0.00006
				(0.0006)
Heating Degree Days				1.061***
				(0.152)
Cooling Degree Days				-1.086***
				(0.144)
Intercept	7.477***	9.221***	7.209***	-9.033**
	(0.765)	(0.008)	(0.384)	(2.612)
Zone FE	No	No	Yes	Yes
Month-Year FE	No	Yes	No	Yes
Adj.R^2	0.119	0.999	0.109	0.999
N	192	192	192	192

Standard errors in parentheses

Dependent variable: Log of monthly average consumption per household.

Treatment starts in March 2022. Zones 1, 2, and 5 are treated; Only Zone 4 serves as the control group.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.3: Regression Results: Monthly Data

	(1)	(2)	(3)	(4)
Treated × Post	-0.110	-0.110*	-0.110	-0.097**
	(0.160)	(0.0550)	(0.156)	(0.023)
Post	-0.266**		-0.266**	
	(0.124)		(0.121)	
Treated	-0.199**	-0.199***		
	(0.088)	(0.030)		
Temperature				1.093***
				(0.081)
Temperature^2				0.0002
				(0.0002)
Heating Degree Days				1.099***
				(0.084)
Cooling Degree Days				-1.124***
				(0.095)
Intercept	7.320***	7.240***	7.200***	-11.53***
	(0.068)	(0.019)	(0.042)	(1.415)
Zone FE	No	No	Yes	Yes
Month-Year FE	No	Yes	No	Yes
Adj.R^2	0.204	0.906	0.244	0.987
N	100	100	100	100

Standard errors in parentheses.

Data up to August 2022. Dependent variable: Log of monthly average consumption per household.

Treatment starts in March 2022. Zones 1, 2, and 5 are treated; Zones 3 and 4 are controls.

Std. errors clustered at zone level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.4: Regression Results: Monthly Data

	(1)	(2)	(3)	(4)
Treated × Post	-0.114	-0.114***	-0.114	-0.099**
	(0.200)	(0.028)	(0.203)	(0.023)
Post	-0.262		-0.262	
	(0.173)		(0.175)	
Treated	-0.042	-0.042***		
	(0.110)	(0.015)		
Temperature				-0.034
				(0.048)
Temperature^2				0.0005
				(0.0004)
Heating Degree Days				-0.023
				(0.043)
Cooling Degree Days				0
				(.)
Intercept	7.163***	7.084***	7.131***	7.484***
	(0.095)	(0.011)	(0.048)	(0.741)
Zone FE	No	No	Yes	Yes
Month-Year FE	No	Yes	No	Yes
Adj.R^2	0.151	0.984	0.131	0.989
N	80	80	80	80

Standard errors in parentheses

Data up to August 2022. Dependent variable: Log of monthly average consumption per household.

Treatment starts in March 2022. Zones 1, 2, and 5 are treated; Only Zone 3 serves as the control group.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.5: Regression Results: Monthly Data

	(1)	(2)	(3)	(4)
Treated × Post	-0.105	-0.105***	-0.105	-0.085**
	(0.198)	(0.033)	(0.200)	(0.021)
Post	-0.271		-0.271	
	(0.171)		(0.173)	
Treated	-0.356***	-0.356***		
	(0.108)	(0.018)		
Temperature				0.865**
				(0.211)
Temperature^2				-0.00003
				(0.0002)
Heating Degree Days				0.880**
				(0.205)
Cooling Degree Days				-0.883**
				(0.205)
Intercept	7.477***	7.395***	7.209***	-7.719
	(0.094)	(0.013)	(0.048)	(3.545)
Zone FE	No	No	Yes	Yes
Month-Year FE	No	Yes	No	Yes
Adj.R^2	0.289	0.980	0.272	0.988
N	80	80	80	80

Standard errors in parentheses

Data up to August 2022. Dependent variable: Log of monthly average consumption per household.

Treatment starts in March 2022. Zones 1, 2, and 5 are treated; Only Zone 4 serves as the control group.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Finally, we used October 2021 as the treatment month and considering only data up to August 2022. Table A.6 shows the results. The coefficient of interest lies in between the value from our main specification in Table 2 and that of the two previous paragraphs.

Table A.6: Regression Results: Monthly Data

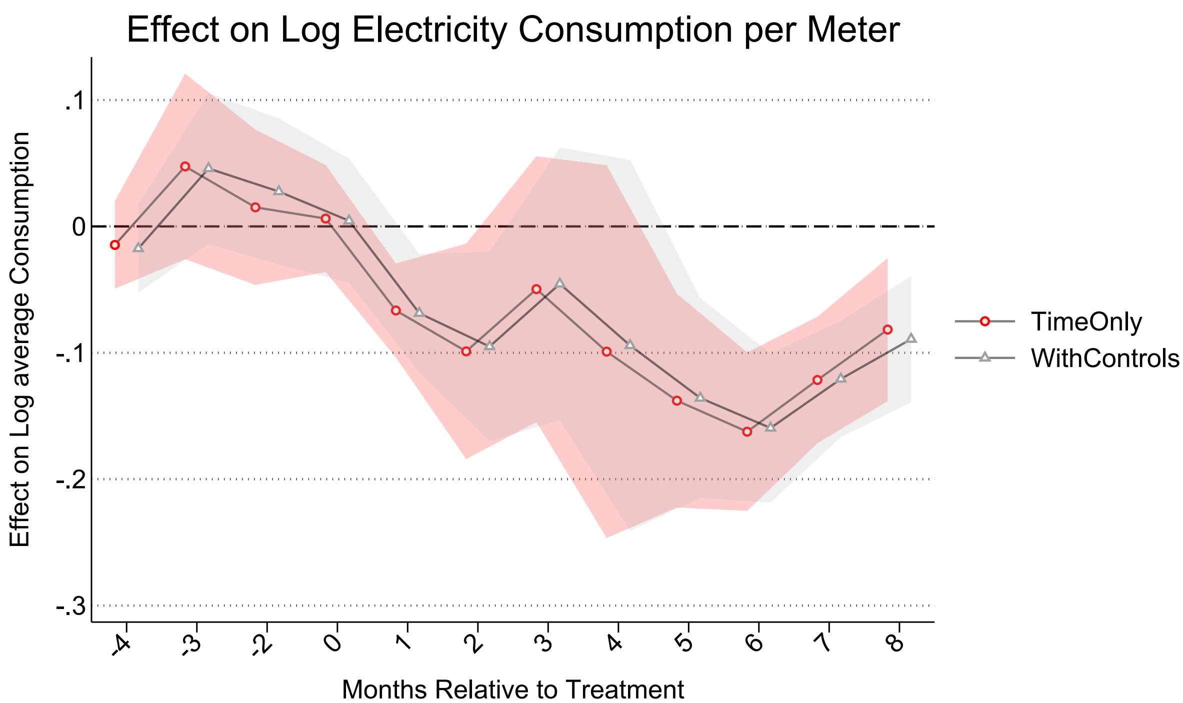
	(1)	(2)	(3)	(4)
Treated × Post	-0.093	-0.093*	-0.093	-0.081***
	(0.161)	(0.051)	(0.158)	(0.016)
Post	0.048		0.0481	
	(0.124)		(0.122)	
Treated	-0.181	-0.181***		
	(0.119)	(0.038)		
Temperature				0.958***
				(0.148)
Temperature^2				-0.00005
				(0.0003)
Heating Degree Days				0.960***
				(0.152)
Cooling Degree Days				-0.981***
				(0.163)
Intercept	7.213***	7.240***	7.105***	-9.161**
	(0.092)	(0.019)	(0.057)	(2.575)
Zone FE	No	No	Yes	Yes
Month-Year FE	No	Yes	No	Yes
Adj.R^2	0.055	0.905	0.090	0.986
N	100	100	100	100

Standard errors in parentheses.
Data up to August 2022. Dependent variable: Log of monthly average consumption per household.
Treatment starts in October 2021. Zones 1, 2, and 5 are treated; Zones 3 and 4 are controls.
Std. errors clustered at zone level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

A.4 Dynamic treatment effects using data up to November 2022

Using the same specification Equation 2 but expanding the sample up to November 2022, we obtain that the decrease in consumption starting in March 2022 continued for several months relative to the control zones. This expands and confirms the findings in Figure 4. These results are shown in Figure A.2.

Figure A.2: Event Study: Dynamic Treatment Effects (Avg. Monthly consumption)



Notes: Each dot represents the effect on log average consumption for each month relative to the treatment date, data up to November 2022. Shaded areas represent the 90% confidence intervals.

A.5 Electricity consumption: Holiday homes

Although consumers spend much less time in holiday homes as their second residency, we test for whether their consumption also dropped due to the price shock. Table A.7 presents the corresponding results for cabins, following the same specification as in Table 2. The coefficients point to a stronger response than in our main results but it is less of a general result for the entire population.

Table A.7: Regression Results: Monthly Data

	(1)	(2)	(3)	(4)
Treated × Post	-0.171***	-0.171***	-0.171***	-0.159***
	(0.019)	(0.022)	(0.019)	(0.017)
Post	2.433***		2.433***	
	(0.006)		(0.006)	
Treated	-0.105	-0.105		
	(0.239)	(0.267)		
Temperature				1.398***
				(0.124)
Temperature^2				-0.0001
				(0.0007)
Heating Degree Days				1.401***
				(0.129)
Cooling Degree Days				-1.407***
				(0.149)
Intercept	4.647***	6.371***	4.584***	-17.48***
	(0.155)	(0.168)	(0.008)	(2.180)
Zone FE	No	No	Yes	Yes
Month-Year FE	No	Yes	No	Yes
Adj.R^2	0.111	0.991	0.107	0.999
N	240	240	240	240

Standard errors in parentheses.
Dependent variable: Log of monthly average consumption per household.
Treatment starts in March 2022. Zones 1, 2, and 5 are treated; Zones 3 and 4 are controls.
Std. errors clustered at zone level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$