

Shifting intra-day electricity consumption through monetary incentives and information feedback

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Based on a report for the Swiss Federal Office of Energy (SFOE)

Motivation

- ▶ Solar energy production takes place during daylight hours
- ▶ Households consume electricity mostly in the evening
- ▶ This mismatch is an issue for the development of solar systems, which could be reduced by:
 - transporting electricity and consume it elsewhere
 - storing electricity for later consumption
 - encouraging households to consume when solar energy is produced

Our contribution in perspective

- ▶ Previous contributions in the field motivate households to *conserve* electricity
 - Recent evidence based on high-frequency meter data:
Degen et al. (*SFOE report* 2013), Di Cosmo et al. (*EJ* 2014),
Jessee & Rapson (*AER* 2014), Ito et al. (*E2e WP* 2015)
- ▶ We induce households to *shift* their consumption towards solar energy production hours (i.e., 11am to 3pm)

Two experiments

1. Treatment 1: information feedback

▶ [Sample letter](#)

- Paper letters (weekly in January, monthly from February to December)
- Information about household's own electricity consumption, and about similar households

Result: no shift, but decrease of consumption

2. Treatment 2: monetary rewards

▶ [Sample letter](#)

- Competition between households
- Ranking based on proportion 11am-3pm and its evolution, controlling for total consumption
- Monetary prizes awarded to the 15 top-ranked households

Result: shift of 2.9 percentage point of the proportion 11am-3pm, thanks to a consumption decrease in the evening

Randomized controlled trial

- ▶ 387 households living in Cernier (Switzerland) contacted
- ▶ 133 households answered our online survey
 - Household and dwelling characteristics
- ▶ 66 households in final sample:
 - Smart meter installed
 - ▶ Electricity consumption (kWh) available in 15-minute intervals (provider *Groupe e*)
 - Flat electricity rate
 - Not involved in other experiments

Stratification

- ▶ Households distributed in 3 groups using a stratification:
 - Electricity consumption per person (1Sep2013 to 30Nov2013)
 - Dwelling size
 - Highest education level achieved by a member of the household

	Control	Treatment 1			Treatment 2		
	Mean	Mean	Δ	t-stat	Mean	Δ	t-stat
Monthly consumption	232.33	277.50	45.17	0.82	226.36	-5.97	-0.15
Monthly consumption per person	100.74	110.85	10.11	0.54	96.98	-3.76	-0.27
Number of people in HH	2.64	2.68	-0.05	-0.30	2.36	0.00	0.00
Dwelling ≥ 100 m ²	0.55	0.50	0.05	0.10	0.55	-0.27	-0.63
Education level	1.86	1.86	0.00	0.00	1.91	0.05	0.17

Group composition

Group	Number of HH
Control	24
Treatment 1 (Information feedback)	20
Treatment 2 (Monetary rewards)	22

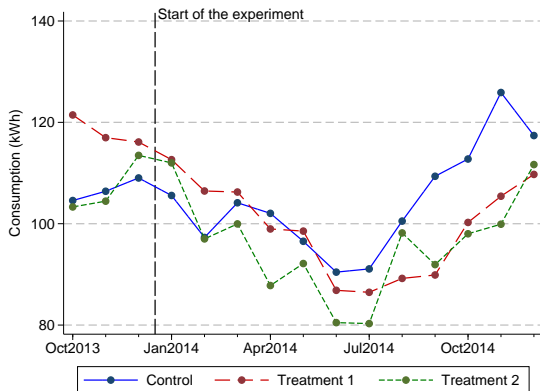
Group characteristics

Before/After

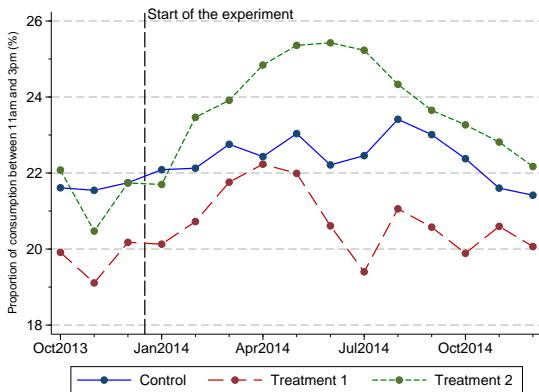
	Control		Treatment 1		Treatment 2	
	Before	After	Before	After	Before	After
Electricity consumed per day (kWh)	7.84 (4.86)	7.54 (5.21)	9.65 (8.80)	8.10 (7.12)	8.05 (5.80)	7.18 (5.69)
Electricity consumed between 11am and 3pm (kWh)	1.70 (1.48)	1.69 (1.55)	1.90 (2.11)	1.69 (1.82)	1.73 (1.71)	1.72 (1.74)
Proportion of electricity consumed between 11am and 3pm	0.20 (0.10)	0.21 (0.10)	0.18 (0.09)	0.19 (0.09)	0.20 (0.10)	0.24 (0.15)
Education level	0.33 (0.47)	0.35 (0.48)	0.25 (0.43)	0.22 (0.41)	0.36 (0.48)	0.36 (0.48)
Age: < 40	0.33 (0.47)	0.35 (0.48)	0.45 (0.50)	0.42 (0.49)	0.27 (0.45)	0.27 (0.45)
Age: 40-49	0.33 (0.47)	0.35 (0.48)	0.10 (0.30)	0.10 (0.31)	0.23 (0.42)	0.23 (0.42)
Age: 50-64	0.12 (0.33)	0.09 (0.28)	0.35 (0.48)	0.37 (0.48)	0.23 (0.42)	0.23 (0.42)
Age: 65+	0.21 (0.41)	0.22 (0.41)	0.10 (0.30)	0.10 (0.31)	0.27 (0.45)	0.27 (0.45)
Number of people in HH	2.46 (1.41)	2.52 (1.41)	2.65 (1.46)	2.68 (1.48)	2.36 (1.26)	2.36 (1.26)
Solar panels	0.29 (0.45)	0.30 (0.46)	0.10 (0.30)	0.10 (0.31)	0.23 (0.42)	0.23 (0.42)
Ecological bulbs > 50%	0.25 (0.43)	0.26 (0.44)	0.30 (0.46)	0.27 (0.44)	0.36 (0.48)	0.36 (0.48)
# Obs.	2,204	7,681	1,834	6,388	2,024	7,346

Standard deviations in parentheses. Before: 01Oct2013-31Dec2013. After: 01Feb2014-31Dec2014.

Monthly consumption per capita

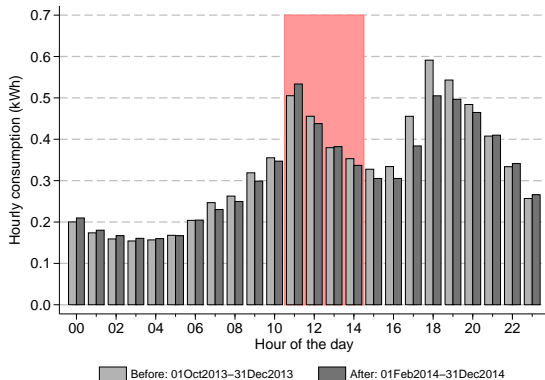


Proportion of consumption 11am-3pm



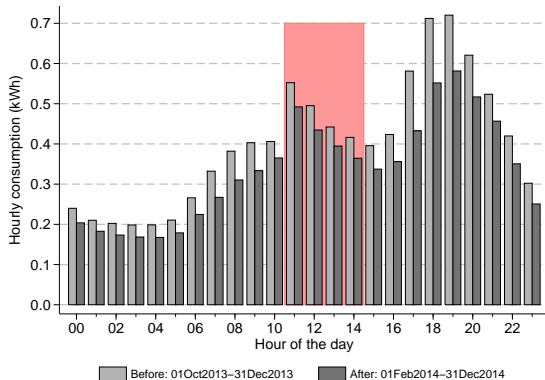
Consumption daily profile

Control



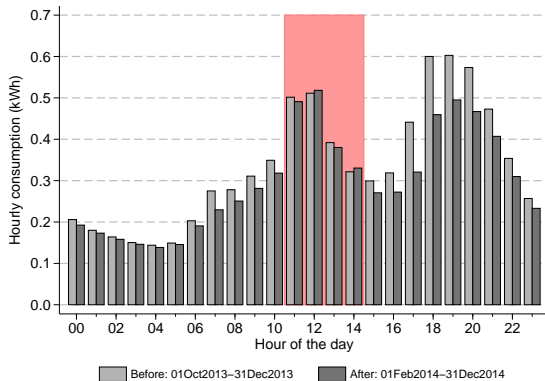
Consumption daily profile

Treatment 1



Consumption daily profile

Treatment 2



Econometric strategy: diff-in-diff

$$Y_{it} = \alpha + \beta_1 D_t + \beta_2 T_{1i} + \beta_3 T_{2i} + \beta_4 (T_{1i} \times D_t) + \beta_5 (T_{2i} \times D_t) + \sum_{k=1}^K \lambda_k X_{kit} + \varepsilon_{it}$$

Where:

- ▶ Y_{it} is (in turn):
 - proportion 11am-3pm for HH i in day t
 - consumption 11am-3pm
 - daily consumption
- ▶ $D_t = \begin{cases} 1 & \text{if } t \geq 01.02.2014 \text{ (After)} \\ 0 & \text{if } 01.10.2013 \leq t \leq 31.12.2013 \text{ (Before)} \end{cases}$
- ▶ $T_{ji} = \begin{cases} 1 & \text{if HH } i \text{ receives treatment } j = 1, 2 \\ 0 & \text{otherwise} \end{cases}$

Estimation method

- ▶ We use linear regression with panel-corrected standard errors (PCSE), because:
 - Small number of HH (panels)
 - Large number of periods (days)
 - Heteroscedasticity
 - Autocorrelation within and across the panels

Results

	OLS			PCSE		
	prop1115	ln(conso1115)	ln(conso)	prop1115	ln(conso1115)	ln(conso)
Constant	0.137*** (0.014)	-1.351*** (0.202)	1.107*** (0.177)	0.137*** (0.008)	-1.208*** (0.070)	1.046*** (0.063)
After	0.001 (0.005)	0.010 (0.087)	0.028 (0.087)	0.002 (0.003)	0.011 (0.033)	0.046 (0.034)
Treatment 1	-0.013 (0.014)	0.003 (0.176)	0.092 (0.165)	-0.013*** (0.003)	-0.001 (0.036)	0.103*** (0.037)
Treatment 1 × After	0.001 (0.006)	-0.116 (0.105)	-0.161 (0.110)	0.001 (0.004)	-0.120*** (0.039)	-0.174*** (0.040)
Treatment 2	-0.007 (0.013)	0.002 (0.159)	0.056 (0.155)	-0.007** (0.003)	0.002 (0.041)	0.066* (0.039)
Treatment 2 × After	0.029 (0.019)	-0.002 (0.098)	-0.123 (0.101)	0.029*** (0.004)	-0.010 (0.046)	-0.132*** (0.044)
Week FE	Yes	Yes	Yes	Yes	Yes	Yes
# Obs.	27,477	27,428	27,477	27,477	27,428	27,477
R ²	0.130	0.331	0.360	0.089	0.158	0.126

*p < 0.10, **p < 0.05, ***p < 0.01. Robust standard errors clustered at household level in parentheses.

Additional controls not reported: see next slide.

▶ T1, prop1115

▶ T1, ln(conso1115)

▶ T1, ln(conso)

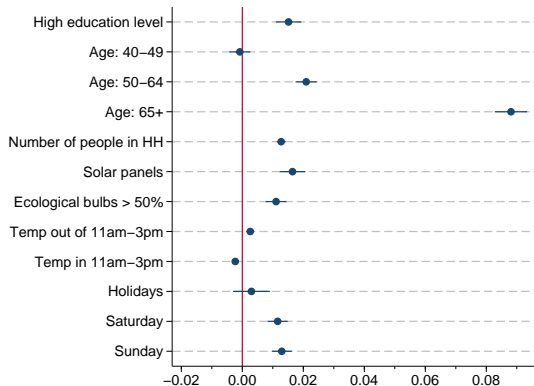
▶ T2, prop1115

▶ T2, ln(conso1115)

▶ T2, ln(conso)

Additional controls

PCSE estimation for prop1115



Findings

- ▶ Monetary incentives do matter:
 - Our findings indicate an average 2.9 percentage points increase in the proportion of consumption between 11am and 3pm
 - This result is achieved by decreasing consumption in the evening while keeping consumption 11am-3pm stable
- ▶ Information feedback do not push households to shift their consumption, however:
 - Households react by decreasing electricity regardless of the period of the day
 - Interpretation of letters maybe not obvious for households
 - ▶ Billing system?

Caveats and further research

- ▶ Very few households
- ▶ One-year experiment: cannot disentangle seasonal effects from timing of the experiment effects
 - Longer experiment
 - Similar experiment starting in a different period of the year or with different waves of households
- ▶ Fixed “solar energy production hours”
- ▶ No time-of-use pricing
- ▶ Data after the end of the experiment
 - Still to be analyzed

Thank You

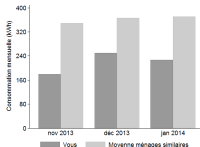


Madame, Monsieur,

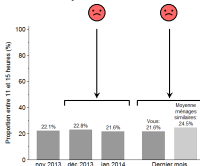
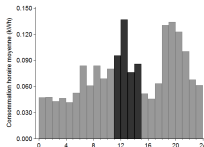
Ce mois, vous avez consommé 226 kWh. Le coût mensuel de l'électricité se monte ainsi à CHF 44.93 (TVA et redevances communales non-comprises). Ces valeurs sont indicatives. Légalement, seule la facture que vous recevrez de Groupe E fait foi.

Par rapport au mois passé, votre consommation a diminué. Votre consommation est actuellement inférieure à la consommation moyenne des ménages similaires.

Neuchâtel, le 3 février 2014










Votre profil de consommation horaire pour le mois écoulé est représenté ci-dessous (graphique de gauche). Votre consommation entre 11 et 15 heures représente 22% de votre consommation totale (graphique de droite). Par rapport au mois précédent, vous avez **diminué** cette proportion. Pour le mois écoulé, votre comportement est **moins bon** que celui de la moyenne des ménages similaires. *Déplacer* votre consommation vers cette plage horaire, sans toutefois augmenter votre consommation totale, permet de limiter l'écart entre production solaire et consommation d'électricité. Un moyen d'atteindre ce but serait par exemple d'enclencher le lave-linge en fin de matinée ou en début d'après-midi.



Merci de l'attention portée à ce courrier. Cordiales salutations,
L'équipe du projet Flexi

Experiment 1: Smileys definition

Smileys	Comparison with proportion in $t - 1$	Comparison with average proportion
	$prop_{it} < prop_{i,t-1} + 4$	$prop_{it} < prop_{\bullet t} + 6$
	$prop_{it} < prop_{i,t-1} + 2$	$prop_{it} < prop_{\bullet t} + 3$
	$prop_{it} < prop_{i,t-1} + .5$	$prop_{it} < prop_{\bullet t} + 1$
	$prop_{i,t-1} - .5 \leq prop_{it} \leq prop_{i,t-1} + .5$	$prop_{\bullet t} - 1 \leq prop_{it} \leq prop_{\bullet t} + 1$
	$prop_{it} < prop_{i,t-1} - .5$	$prop_{it} < prop_{\bullet t} - 1$
	$prop_{it} < prop_{i,t-1} - 2$	$prop_{it} < prop_{\bullet t} - 3$
	$prop_{it} < prop_{i,t-1} - 4$	$prop_{it} < prop_{\bullet t} - 6$



Projet Flexi

Neuchâtel, le 3 février 2014

Madame, Monsieur,

Dans le cadre du projet Flexi, votre ménage a été sélectionné pour prendre part à une expérience qui va se dérouler entre janvier et décembre 2014. Votre participation n'implique aucun coût ni engagement, mais pourrait vous permettre de gagner des récompenses en espèces.

Chaque mois, les 22 ménages participant à l'expérience seront classés en fonction de la proportion d'électricité consommée entre 11 et 15 heures. Votre objectif est de maximiser la *part* d'électricité que vous consommez dans cette tranche horaire. Autrement dit, votre objectif est de *déplacer* votre consommation vers cette tranche horaire, sans toutefois augmenter votre consommation totale. Un moyen d'atteindre ce but serait par exemple de programmer votre machine à laver le linge afin qu'elle démarre à 11 heures. Les ménages dont la consommation augmente artificiellement seront exclus du classement.

Chaque mois, les récompenses suivantes seront distribuées (en espèces) :

1^{er}-5^{ème} : 50 CHF 6^{ème}-10^{ème} : 30 CHF 11^{ème}-15^{ème} : 10 CHF

Le mois passé, votre ménage s'est classé 12^{ème} et vous recevez donc **10 CHF** :









Des informations détaillées concernant la façon d'établir le classement sont disponibles sur le site web du projet. Le classement anonymisé est disponible sur <http://www.unine.ch/flexirank>. Votre ménage y est identifié à l'aide du code EC33tp.

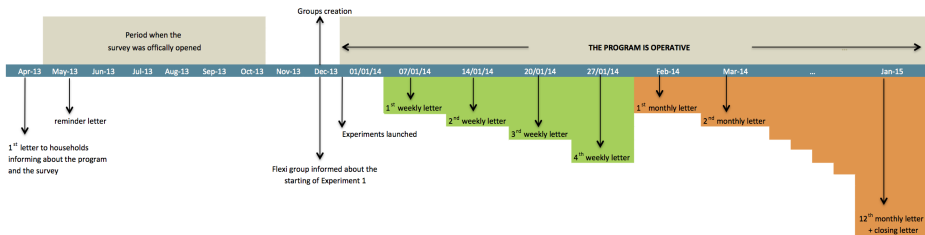
Merci de l'attention portée à ce courrier. Cordiales salutations,

L'équipe du projet Flexi

Experiment 2: Monetary rewards and smileys

Smileys	Rank	Prize (CHF)
	1-5	50
	6-10	30
	11-15	10
	16-20	—
	21-22	—
	<i>out</i>	—

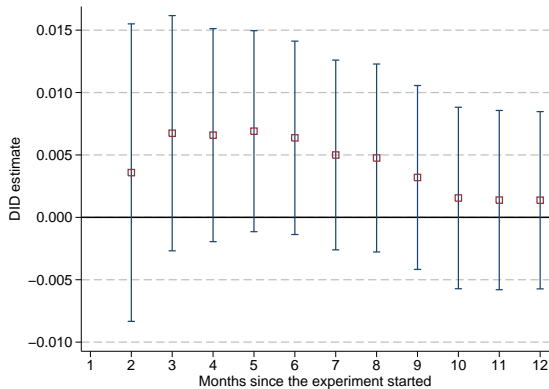
Timeline of the project



Treatment 1: After period accumulates month-by-month

Proportion 11am-3pm, PCSE

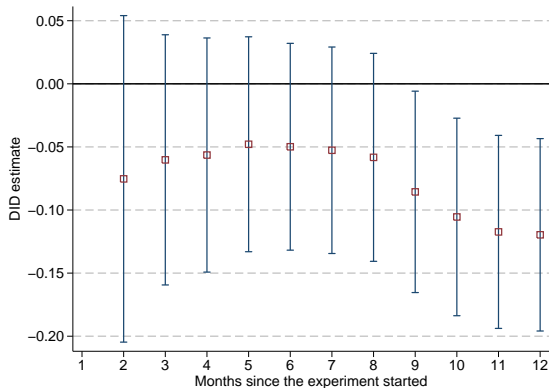
◀ Results



Treatment 1: After period accumulates month-by-month

Consumption 11am-3pm, PCSE

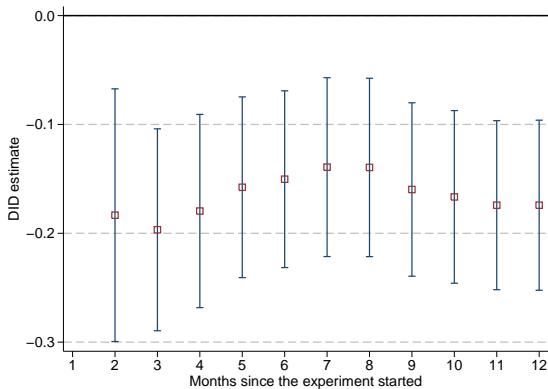
◀ Results



Treatment 1: After period accumulates month-by-month

Total consumption, PCSE

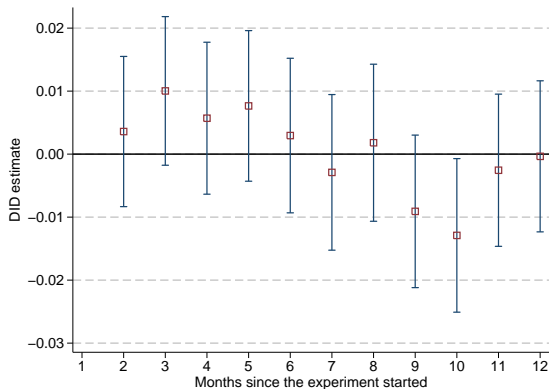
◀ Results



Treatment 1: After period moves month-by-month

Proportion 11am-3pm

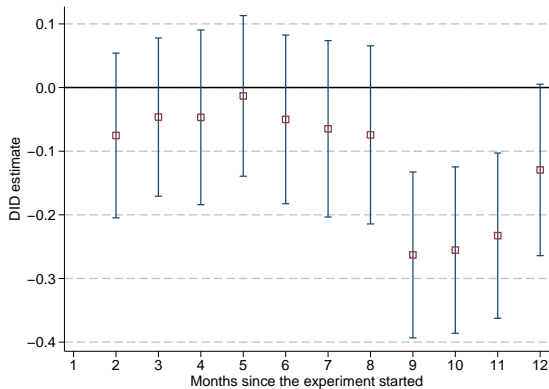
◀ Results



Treatment 1: After period moves month-by-month

Consumption 11am-3pm

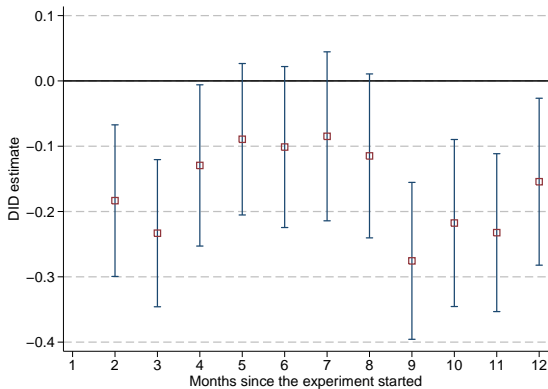
◀ Results



Treatment 1: After period moves month-by-month

Total consumption

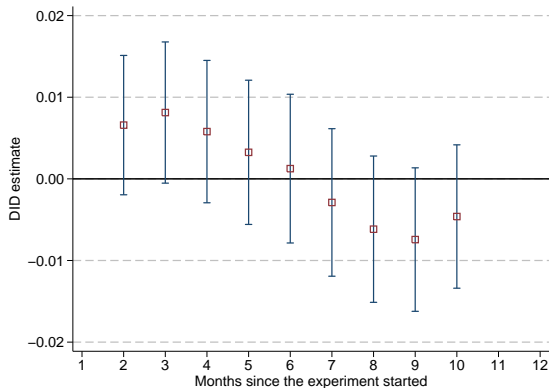
◀ Results



Treatment 1: After period moves 3 months-by-3 months

Proportion 11am-3pm

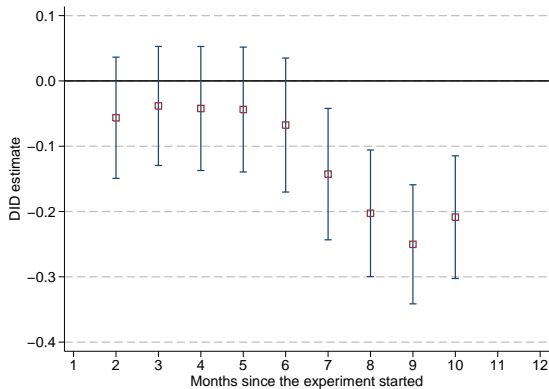
◀ Results



Treatment 1: After period moves 3 months-by-3 months

Consumption 11am-3pm

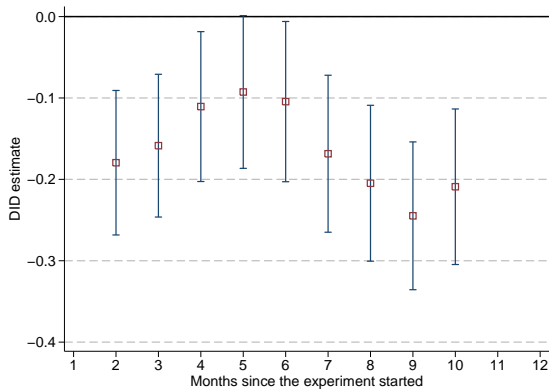
◀ Results



Treatment 1: After period moves 3 months-by-3 months

Total consumption

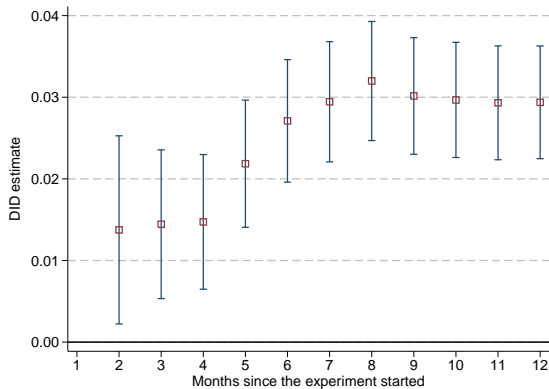
◀ Results



Treatment 2: After period accumulates month-by-month

Proportion 11am-3pm, PCSE

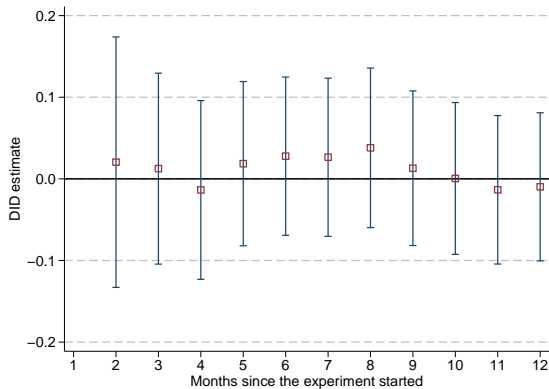
◀ Results



Treatment 2: After period accumulates month-by-month

Consumption 11am-3pm, PCSE

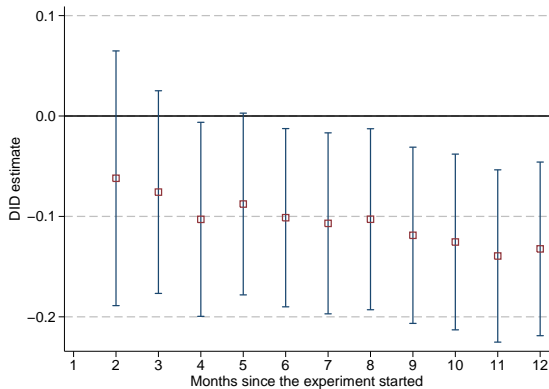
◀ Results



Treatment 2: After period accumulates month-by-month

Total consumption, PCSE

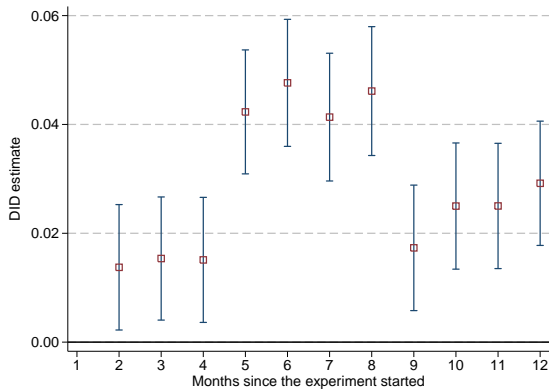
◀ Results



Treatment 2: After period moves month-by-month

Proportion 11am-3pm

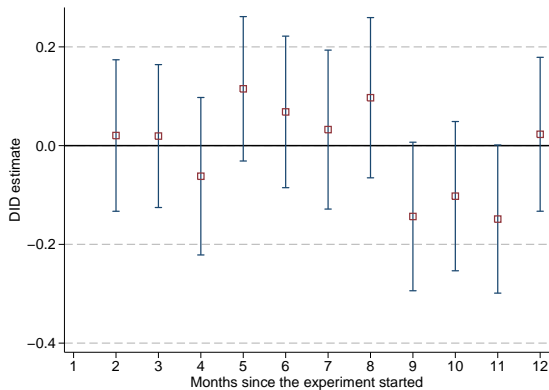
◀ Results



Treatment 2: After period moves month-by-month

Consumption 11am-3pm

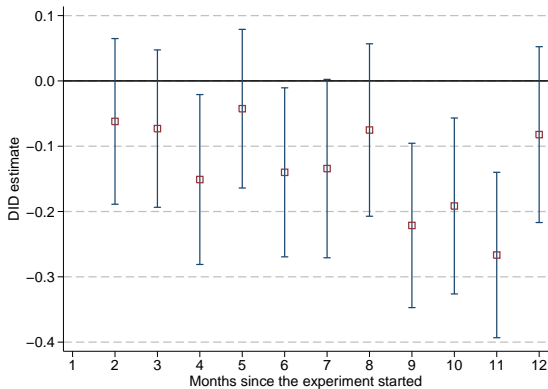
◀ Results



Treatment 2: After period moves month-by-month

Total consumption

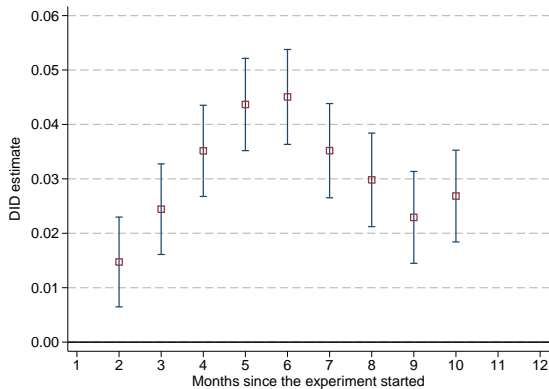
◀ Results



Treatment 2: After period moves 3 months-by-3 months

Proportion 11am-3pm

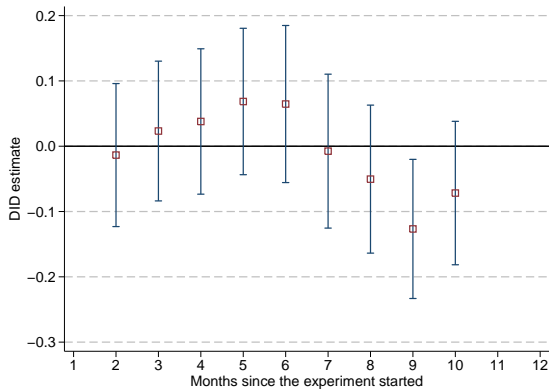
◀ Results



Treatment 2: After period moves 3 months-by-3 months

Consumption 11am-3pm

◀ Results



Treatment 2: After period moves 3 months-by-3 months

Total consumption

◀ Results

