



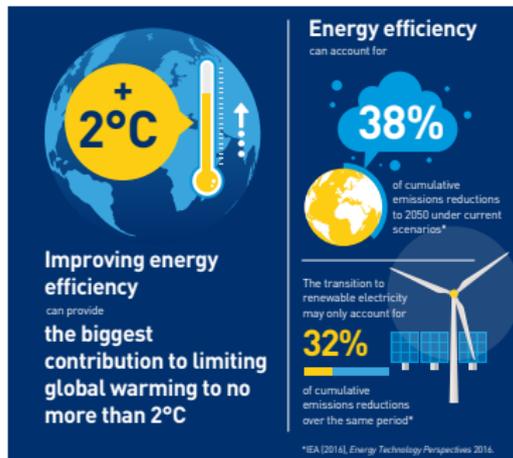
Home Energy Audits: What Can We Learn from a Field Experiment?

Nina Boogen, ETH Zürich

joint work with Claudio Daminato, Massimo Filippini and Adrian Obrist

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Motivation



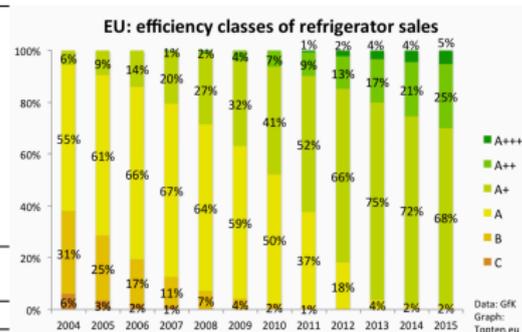
Source: Carbon Trust

- Large potential of energy efficiency improvements in the residential sector.
- It has long been suggested that consumers fail to make investments in energy efficiency even when it would be financially beneficial to take them.
- Why?
 - market failures: principal-agent issues, credit constraints...
 - behavioural anomalies: present bias, low computational skills...

Energy efficiency gap for home appliances?

	Fridge 1	Fridge 2
Model	Bosch KGV36VB32S	Bosch KGE36VW4A
Energy efficiency class	A++	A+++
Height	186 cm	186 cm
Width	60 cm	60 cm
kWh/year	226	161
Electricity costs/year	45 CHF	32 CHF
Price	759 CHF	789 CHF
Lifetime costs (15 years)	1434 CHF	1269 CHF
Annual monetary savings		13 CHF
Savings over lifetime		165 CHF
Implicit discount rate $NPV_1 = NPV_2$		0.45

Source: Fust.ch



- What explains the choice of Fridge 1 (A++)?
 - Rational preferences?
 - Limited knowledge about energy costs?

⇒ **Lack-of knowledge about energy costs** might systematically affect the consumers' valuation of energy efficiency.

This paper

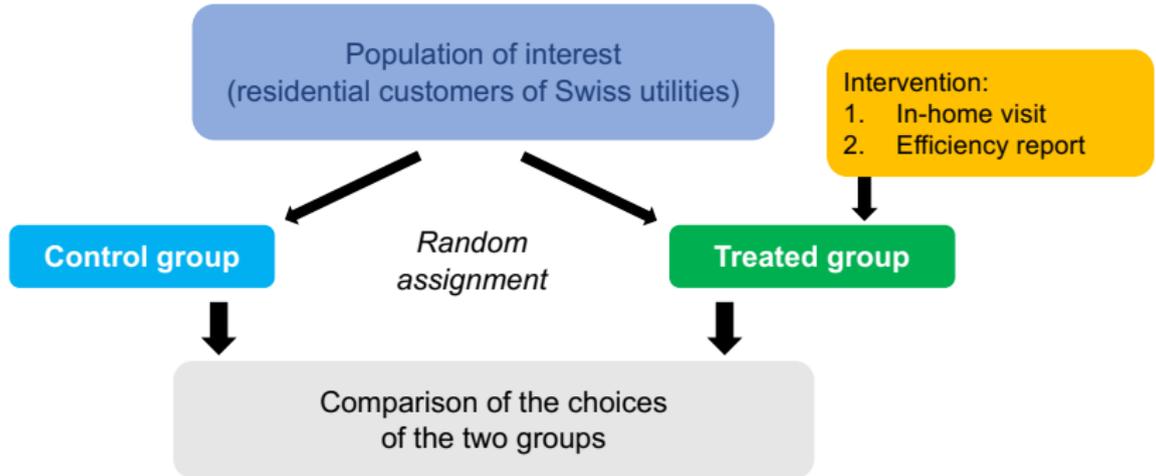
Does limited knowledge about the monetary costs of using energy consuming durables induce households to underinvest in energy efficiency?

- Households choices of purchase of *home appliances* and *light bulbs*
- Evidence of substantial lack-of knowledge of electricity prices, costs of running appliances and investment computation capacity
- Study the role of limited knowledge about energy costs in:
 - the **replacement of existing durables** with new efficient ones
 - the **energy efficiency of the newly purchased** durables
- Results from a *randomized field experiment* with around 600 households in Switzerland:
 - **in-home visits** to collect unique data on existing durables
 - **tailored** informational treatment

Contributions

1. **Information treatments and individuals' decision making** (Chetty and Saez 2013, Bhargava and Manoli 2015, Liebman and Luttmer 2015)
 - Information provision impacts behavior for retirement, take-up of social benefits
 - *Does a tailored information treatment affect consumers' actual choices of home appliances?*
2. **Explanations for the energy efficiency gap** (Gillingham and Palmer 2014, Houde 2018; Fowlie et al. 2018, Allcott and Knittel 2019)
 - Mixed evidence about the existence of the energy efficiency gap
 - *We show that consumers are not fully informed about the monetary costs of using home appliances.*

Randomised control trial (RCT)



⇒ The experiment is administered in collaboration with two Swiss local utilities (areas of Lugano and Winterthur).

Experimental design

March 2017	September 2017	October 2017 - February 2018	September 2018	October 2018 - February 2019
Allocation to Treatment (<i>N</i> =29,000)	Completed Survey (<i>N</i> =1,575)	In-home visits Information provision (<i>N</i> =510)		Follow-up (<i>N</i> =443)
Allocation to Control (<i>N</i> =11,000)			Completed Survey (<i>N</i> =638)	In-home visits Survey purchases (<i>N</i> =219)

Intervention part I: in-home visits

- Goal: collect data on the energy efficiency of **existing appliances and lighting**
- Research assistants used an online survey tool and a tablet:
 - information on major appliances at home (e.g., **time of purchase**)
 - pictures of the **appliances nameplates** (fridge, separate freezers, dishwashers, washing machines and tumble dryers)
 - number of halogen and LED bulbs at home
- No information about energy efficiency provided at this stage.
- Information on **appliances energy efficiency** (*energy efficiency class, kWh/year*) recovered from the nameplates after the in-home visits.

Intervention part II: information provision

Letter sent at the participants' home with brief **energy efficiency report**:

- guidelines on how to read the information reported
- one table for each appliance:

Washing machine			
Characteristics of your washing machine: Producer: Miele, Width: 60 cm, Height: 80 cm, Year of purchase: 2012			
	Your appliance	Alternative appliance on the market (load capacity 8 kg)	
		A++	A+++
Consumption per cycle	1.020 kWh	1.17 kWh	0.47 kWh
Cost of one cycle	0.189 CHF	0.216 CHF	0.087 CHF
Annual operating costs ⁽ⁱⁱ⁾	42 CHF	48 CHF	19 CHF
Approximate price range of new appliance (from... to...)		725-2309 CHF	440-4099 CHF
Estimate of potential annual savings on operating costs (compared to current appliance)		No savings	23 CHF

- **energy costs (annual monetary costs)** of existing appliance and that of similar efficient appliances available on the market
- **potential of monetary savings** from the adoption of A++ vs A+++ new appliance compared to existing appliance (*annual operating costs*)

(ii) The annual operating costs for the washing machine are estimated assuming 220 washing cycles.

Data

- We combine data from the baseline household survey, in-home visits and follow-up:
 - pre-treatment information on households socio-demographics, respondents' energy-related knowledge and financial literacy, environmental attitudes
 - purchase decisions of energy-using durables:
 - ▶ electricity consumption (kWh/year) and energy efficiency class (A+++,A++,...) of home appliances purchased in years 2016-2018
 - ▶ reason replaced existing appliance (defective or not)
 - ▶ type of light bulbs (halogen, energy saving, LED) in year 2018
- Final sample: 631 households (415 treated and 216 control)
- Choices post-treatment:
 - 115 households purchased at least one new home appliance
 - 447 households purchased at least one new light bulb

Balance statistics

	Control	Treatment	<i>t</i> -test
Female	0.296	0.374	(-1.94)
Age	59.051	55.711	** (3.26)
Household size	2.524	2.614	(-0.90)
Couple	0.792	0.743	(1.36)
Tertiary education	0.477	0.575	* (-2.36)
Income below 6000 CHF	0.236	0.182	(1.61)
Tenant	0.176	0.219	(-1.28)
Multi-family house	0.273	0.313	(-1.04)
Energy-related knowledge	1.635	1.804	(-1.60)
Investment literacy	3.097	3.206	(-1.55)
Environmental values	5.663	5.571	(1.06)
<i>p</i> -value of F-test of joint significance		0.006	
N	216	415	631

Empirical analysis

We estimate the simple model:

$$Y_i = \beta D_i + \delta X_i + \epsilon_i$$

- Y_i : indicator of durable choices of household i
 - whether at least one new home appliance/light bulb has been purchased in the year after treatment
 - whether a non-defective existing appliance has been replaced with a new one
 - energy efficiency of the newly purchased durables:
 - ▶ home appliances: (i) electricity consumption (kWh/year); (ii) energy label (A+++);
 - ▶ light bulbs: (i) at least one energy saving or LED bulb; (ii) no halogen;
- D_i : treatment indicator
- X_i : set of respondent's and household's pre-treatment characteristics
- Identification: $(Y_1, Y_0)T|X$ and common support

Results – Probability of purchase/replacement

<i>Panel A: Home appliances</i>	New purchase		Replacement not defective	
	(1)	(2)	(3)	(4)
Treatment	-0.014 (0.032)	0.008 (0.035)	0.039* (0.021)	0.057** (0.024)
Controls	No	Yes	No	Yes
Observations	631	544	631	544
Dependent variable mean control	0.189	0.181	0.028	0.020

<i>Panel B: Light bulbs</i>	New purchase	
	(1)	(2)
Treatment	0.049 (0.038)	0.086** (0.040)
Controls	No	Yes
Observations	631	544
Dependent variable mean control	0.676	0.688

Notes: Marginal effects from Probit model reported.

Results – Efficiency of newly purchased durables

<i>Panel A: Purchased home appliances</i>	Electricity consumption (Log average)	
	(1)	(2)
Treatment	-0.186*** (0.050)	-0.149** (0.071)
Controls	No	Yes
Observations	115	101
Dependent variable mean control	5.399	5.404

<i>Panel B: Purchased light bulbs</i>	At least one LED	
	(1)	(2)
Treatment	0.072*** (0.025)	0.083*** (0.028)
Controls	No	Yes
Observations	447	389
Dependent variable mean control	0.870	0.869

Notes: OLS estimates reported in panel A.
Marginal effects from Probit model reported panel B.

Main findings

- Our information treatment induces a substantial durable choices response:
 - Probability of replacement
 - ▶ **6 percent increase** in the probability of replacement of non-defective existing appliances
 - ▶ **9 percent increase** in the probability of buying at least one new light bulb
 - Conditional on purchasing a new durable:
 - ▶ **decrease of 15 percent** in the electricity consumption of newly purchased home appliances
 - ▶ probability to purchase at least one LED **increases by 8 percentage points**
- Possible mechanism: Households seem to accumulate energy-related knowledge following the information treatment

Conclusions

- We provide *experimental evidence* that (some) **consumers do not fully incorporate information about energy costs** when purchasing home appliances and light bulbs.
- What works? Informational intervention:
 - addressing lack-of knowledge about energy costs *tailored* to the households' existing stock of durables
 - provided with a letter that remains available to the households until the time of purchase
 - following a visit at home
- Future work: heterogeneity, intensity of the treatment.

QUESTIONS?

Thank you for your attention...

nboogen@ethz.ch
@NinaBoogen



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BACKUP

Limited knowledge and purchase of energy-consuming durables

- A consumer will choose to purchase an energy-consuming durable A over B ($e^B > e^A$) only if:

$$\underbrace{\Gamma \left(\sum_t \delta^t (e_t^B - e_t^A) \right)}_{\text{energy savings}} + \underbrace{\theta}_{\text{non-monetary benefits}} > \underbrace{P^A - P^B}_{\text{investment}} + \underbrace{\gamma}_{\text{non-monetary costs}}$$

- Γ : valuation weight in the presence of behavioural anomalies
 - present bias
 - limited attention due to salience bias...
 - **limited knowledge about energy costs**

$$H_0 : \frac{\Delta \Gamma}{\Delta(\text{Informational treatment})} = 0$$

Nameplate

LIEBHERR

GNP 3013 Index 20B / 006
Service-Nr./No.Service: 0986076-02

GEFRIERSCHRANK-NO-FROST-SUPER A
FREEZER-NOFROST
CONGÉLATEUR-NOFROST
CONGELADOR-NOFROST
МОРОЗИЛЬНИК-NOFROST

Liebherr Hausgeräte GmbH
Memminger Str. 71-73
D-88418 Gisingen/Hausen

Klasse/Class Classe/Clase	Ap-Typ/AP-Type AP-Type/AP-Tipo	Bruttinhalt/Gross Capacity Volume Brut/Capacidad Bruta	Gefriervermögen/Freezing Capacity Pouvoir de Congel./Capac. Congeladora
SN-T	3 6304 4	304 l	20kg/24h

Nutzhalt Net Capacity Volume Utile Сарас. Утил	Ges / K / I / G / KE / KALT Tot / R / F / C / CA / CHILL Tot / R / I / C / CA / CHILL Tot / F / C / BO / CHILL
261 l	/261 l

R600a: 48g
259 W 1.3 A 220-240 V ~ 60 Hz
Serial-Nr. 30.431.594.7

CE

Insulation (Pentan)
Made in Germany/ Сделано в Германии
346

Intervention part II: information provision (lighting)

Lighting			
	Halogen	Energy Saving	LED
Total number of light bulbs	29	13	5
Annual cost per light bulb ⁽¹⁾	8.51 CHF	2.22 CHF	1.11 CHF
Total annual costs	247 CHF	29 CHF	6 CHF

Price of the light bulb	4 CHF	6 CHF	5 CHF
Lifetime	2 years	10 years	15 years
Total cost of one bulb for 10 years	105 CHF	28 CHF	14 CHF
Estimated annual saving in Francs for each Halogen light bulb replaced	-	6.29 CHF	7.40 CHF

⁽¹⁾ The estimation of the annual electricity consumption for each light bulb has been performed assuming the usage of light bulbs that exhibit similar luminosity (700 lm) and light color (2500 K). This corresponds to a capacity of 46 W for halogen, 12 W for energy saving and 6 W for LED light bulbs. Additionally, it was assumed that every light bulb was used for 1000 hours per year.

- We estimate that you can save approximately CHF 215.- in annual electricity costs by replacing your 29 Halogen light bulbs with LED bulbs!
- If you replace your 29 Halogen light bulbs with LED bulbs, you can save approximately CHF 2639.- in total electricity costs for lighting in 10 years!

- number of light bulbs at the participant's home, distinguishing by light bulb type (*halogen, energy saving, LED*)
- annual electricity consumption of each light bulb type (*one light bulb and total*)
- estimate of the **monetary savings potential** from replacement of the existing halogen bulbs with efficient bulbs (*annual and in 10 years*)

Sample characteristics

	Sample	Switzerland
Household size	2.6	2.9
Share with tertiary education	0.54	0.35
Median eq. monthly household income (,000 CHF)	(3.8-5.7)	4.2
Share employed	0.57	0.59
Home-ownership rate	0.79	0.45

Balance statistics by utility

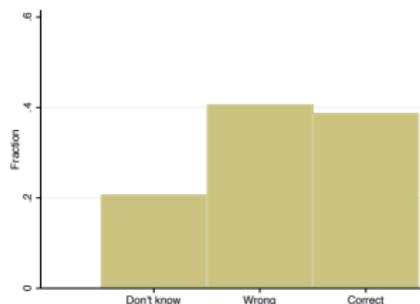
	Winterthur			Lugano		
	Control	Treatment	<i>t</i> -test	Control	Treatment	<i>t</i> -test
Female	0.344828	0.368421	(-0.39)	0.263566	0.380435	* (-2.17)
Age	55.104651	53.407895	(1.01)	61.682171	58.565217	** (2.65)
Household size	2.464286	2.623894	(-1.00)	2.563492	2.602210	(-0.30)
Couple	0.747126	0.745614	(0.03)	0.821705	0.739130	(1.72)
Tertiary education	0.747126	0.736842	(0.19)	0.294574	0.375000	(-1.48)
Income below 6000 CHF	0.206897	0.135965	(1.55)	0.255814	0.239130	(0.34)
Tenant	0.344828	0.296943	(0.82)	0.062016	0.123656	(-1.81)
Multi-family house	0.482759	0.462882	(0.32)	0.131783	0.129032	(0.07)
Energy-related knowledge	1.916667	1.929204	(-0.08)	1.443548	1.646067	(-1.39)
Investment literacy	3.287356	3.285088	(0.02)	2.968992	3.108696	(-1.34)
Environmental values	5.426471	5.397059	(0.23)	5.820312	5.852941	(-0.27)
<i>p</i> -value of F-test of joint significance		0.981			0.1052	
N	87	229	316	129	186	315

Attrition analysis

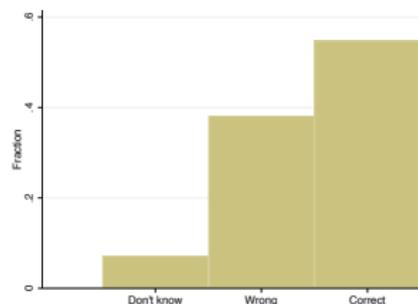
	(1)	(2)
	<i>Audit</i>	<i>Follow-up</i>
Treatment	-0.0421 (0.0263)	
Controls		Yes
<i>p</i> -value of F-test of joint significance		0.746
N	1765	429
R^2	0.001	0.018

- **No significant differential attrition** between treatment and control group (from survey to taking the in-home visit)
- No evidence of non-random selection into the follow-up survey for the treated

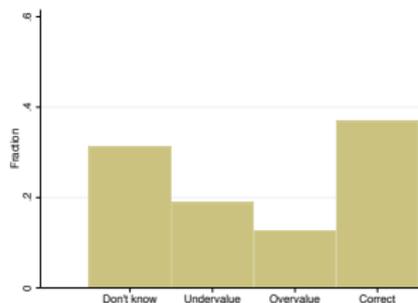
Energy-related knowledge in the data



(a) Cost washing cycle

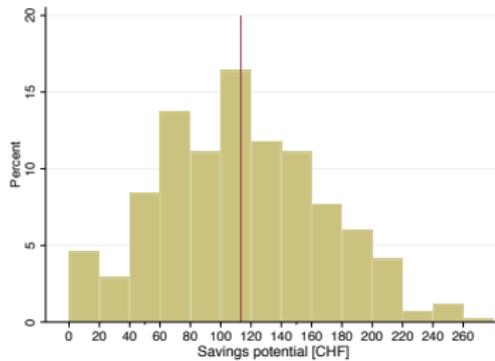


(b) Savings LED

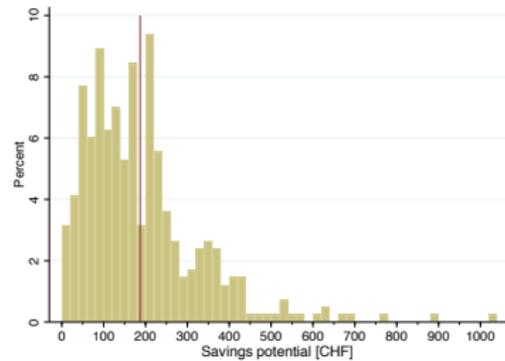


(c) Electricity price

Potential of monetary savings for the treated



(a) Home appliances



(b) Lighting

Placebo intervention pre-treatment

<i>Purchased home appliances</i>	Electricity consumption (Log average)	
	Post (2018) (1)	Pre (2016-2017) (2)
Treatment	-0.149** (0.071)	0.002 (0.029)
Controls	Yes	Yes
Observations	101	211
Dependent variable mean control	5.39	5.36

Notes: OLS estimates reported in Columns (1) and (2).

Mechanisms: energy-related knowledge of treated

Share of correct answers to literacy questions treated group, pre vs post treatment

	<i>Pre</i>	<i>Post</i>	<i>t-test</i>
Knowledge electricity prices	0.308	0.333	(0.74)
Knowledge costs washing cycle	0.510	0.608	** (2.74)
Knowledge costs running desktop pc	0.395	0.562	*** (4.74)
Knowledge savings LED	0.572	0.579	(0.22)
<i>N</i>	415	415	830