How Many Economists does it take to Change a Light Bulb? A Natural Field Experiment on Technology Adoption

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FEEM - 11/10/2017

Motivation

- **The energy paradox:**

1. Despite the fact that replacing 1 incandescent light bulb in every American household with a CFL would prevent the equivalent annual greenhouse gas emissions from **420,000 cars** and **save $806 million** in annual energy cost,
2. 70% of residential households have 1 CFL but **only 11% of potential sockets have CFLs**

- How to **encourage adoption and diffusion** of energy saving technology?

1. What **discipline** (economics, psychology) provides the most effective means of motivating adoption?
2. What is the effect of a **price change**?
3. What is the effect of a **frame change** involving **social norms**?

- Our aim is to answer to these questions using a **large scale natural field experiment** selling CFLs **door-to-door** in the suburbs of Chicago

Sample of the previous literature

- **Social Psychology:**

1. Goldstein, Cialdini and Griskevicius (2008)
2. Schultz *et al.* (2007)

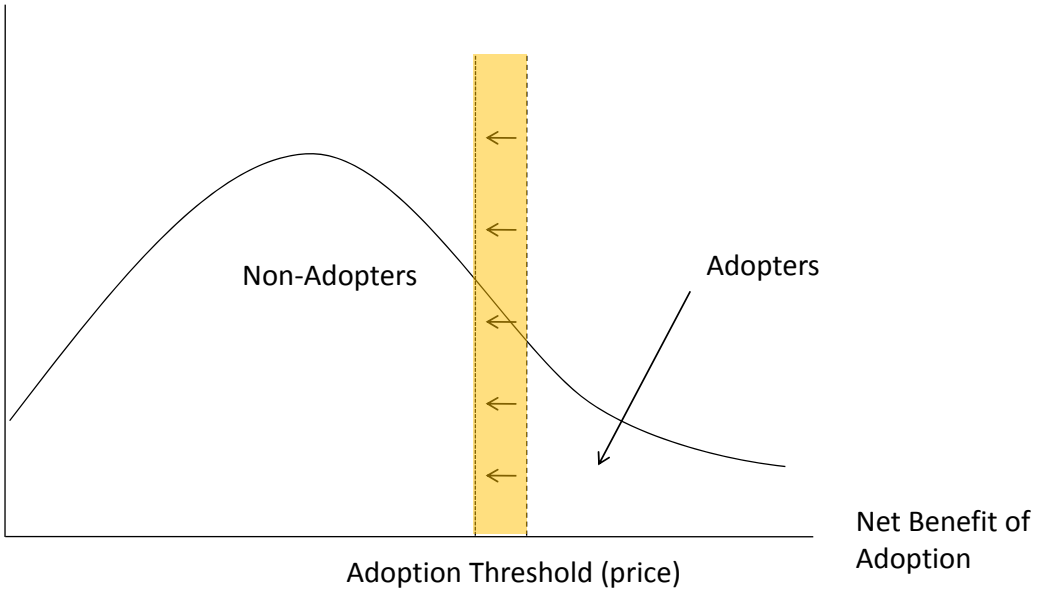
- **Economics**

1. Griliches (1957)
2. Jaffe and Stavins (1995)
3. Gallagher and Muehlegger (2008)
4. Hall (2004)

- **Social norms**

1. Allcott (2009)
2. Ferraro and Price (2010)
3. **DellaVigna List and Malmendier (2012)**

Technology adoption I: subsidy

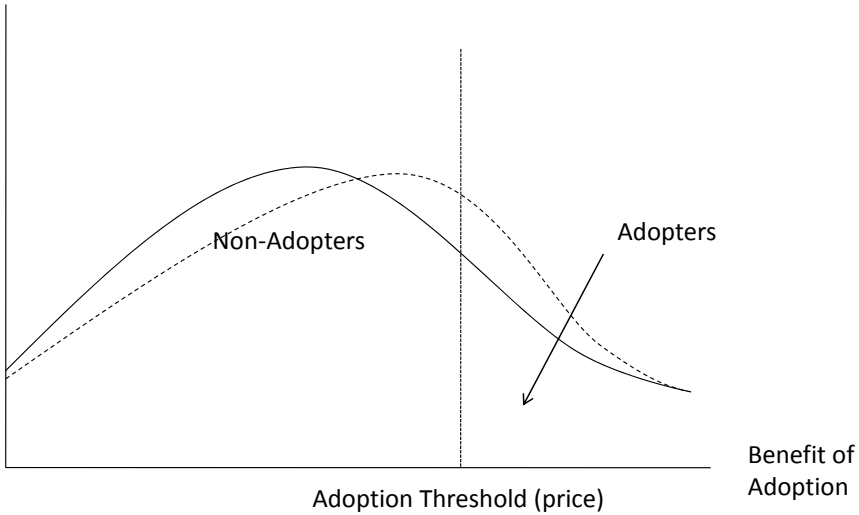


- Assume there is a population of (heterogeneous) potential consumers whose WTP distributes according to some distribution, which depends upon:

1. **Observable** characteristics (location, income, gender, etc…)
2. **Unobservable** characteristics (social preferences, environmental concerns, discounting, ambiguity aversion, etc...)

- A **subsidy** on the purchasing price has the effect of increasing consumption, shifting the threshold that identifies the marginal buyer

Technology adoption II: nudges via social norms



- **Nudges**, instead, manipulate subjects' concerns (i.e., yield a structural break in subjects' preferences). This, in turn, modifies the shape of of the distribution of households' WTP.
- Folloving **DLM12**, we explore the impact of a nudge based on **social norms** built upon the **relative distance** with respect to the reference group:

1. **SNL:** *"For instance, did you know that 70% of **US households** owns at least one CFL?"*
2. **SNH**: *"For instance, did you know that 70% of households we **surveyed in this area** owns at least one CFL?"*

Experimental design: door-to-door layout

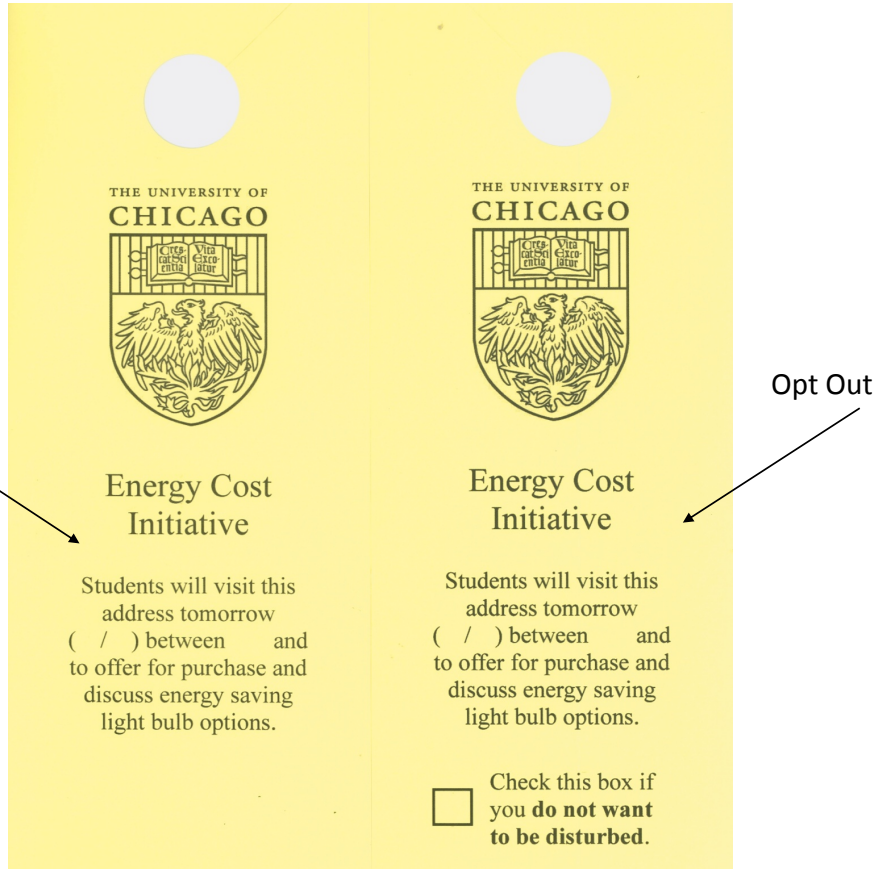
- Suburbs of Chicago (Libertyville, Lemont, Roselle, Arlington Heights, Glen Elyn)
- Mapped neighborhoods into treatment groups by street
- Hired students to approach households on week-ends to sell **1 or 2 packs** (4 bulbs each) of CFLs
- Students approach approx. 25 households per hour
- Typically change to new treatment after each hour
- 4 hours of work: 10am-11am, 11am-noon, 1pm-2pm and 2pm-3pm

Experimental design: warning levels

- **With the exception of the NW treatment**, our team approached households the day prior to the experiment and hung door-hangers on doors announcing arrival the following day

- Three "**warning levels**":

1. No Warning (**NW**)
2. Warning (**W**)
3. Opt out (**OO**)



Experimental design: implementation

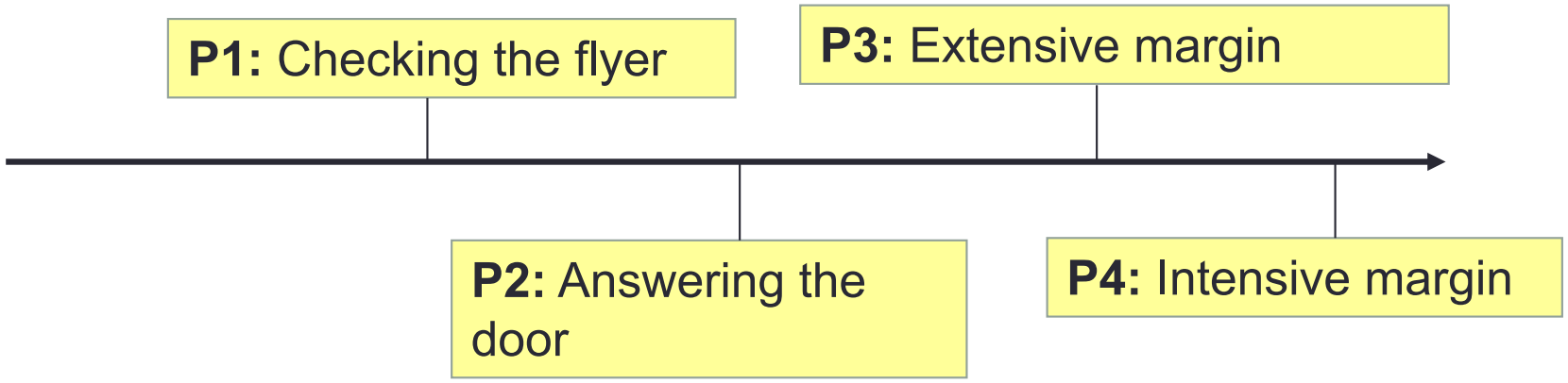
Table 1: Treatment Sample Size

Price per Pack	Social Norm	No Warning	Warning	Opt-Out
$1	No	480	474	473
	Low	447	508	535
	High	454	469	481
$5	No	435	546	501
	Low	493	544	491
	High	431	511	542
Total		2740	3052	3023

Each cell gives the number of households approached for each treatment group

- We approached a total of **8,815** households involved under **3x3x2=18 randomized** treatment conditions.
- Two price levels: $ 1 and $ 5
- Three social pressure levels (N, L, H)

Experimental design: timing



- We model subjects' decisions as a **sequence of 4 binary choices**
- Social norms and prices are revealed in Phase 3, after answering the door

Descriptive stats I: answering the door

Table 2: The Decision to Answer to Door in Warning Treatments

	Check | Answered	Answer Door	Purchased	Purchased | Answered	Q=2 | Purchased
No Warning		0.367	0.0321	0.087	0.443
		(0.482)	(0.176)	(0.283)	(0.500)
		2740	2740	1006	88
Warning		0.332	0.038	0.115	0.564
		(0.471)	(0.192)	(0.320)	(0.498)
		3052	3052	1014	117
Opt-Out	0.116	0.274	0.028	0.103	0.529
	(0.321)	(0.446)	(0.165)	(0.307)	(0.502)
	3023	3023	3023	828	85
Total	0.116	0.323	0.033	0.102	0.517
	(0.321)	(0.468)	(0.178)	(0.302)	(0.500)
	3023	8815	8815	2848	290

Households that chose to "Opt Out" oare 352 households of the 3023 and are included as doors knocked on but not answered.

- Checking rate (OO) of **11%** overall
- Answer rate of **32%** overall.
- **Extensive margin:** a purchase rate of (**3%**) (**10%**) (un)conditional on answering the door.
- In this respect, our evidence is in line with the literature on the **energy paradox**.

Reduced form: answering the door

- We employ a simple linear probability model to estimate (social pressure) treatment effects on the probability of opening the door.

Table 3: The Decision to Answer the Door: OLS.

	(1)	(2)	(3)
Warning	-0.035**	-0.038**	-0.026*
	(0.017)	(0.016)	(0.015)
Opt-Out	-0.093***	-0.087***	-0.077***
	(0.017)	(0.017)	(0.017)
Constant	0.367***	0.400***	0.351***
	(0.013)	(0.024)	(0.027)
Surveyor Effects	No	Yes	Yes
City Effects	No	No	Yes
N	8815	8815	8815

$*p < .1$; $**p < .05$; $***p < .01$

- Main results:

1. **Social pressure:** Warning (W/OO) reduce the likelihood of answering:
2. **Sorting:** the OO treatment reduces the likelihood compared to W (p<1%)

Descriptive stats: purchase decisions

Table 4: The Decision to Purchase Un/conditional on Answering Door

	Purchased			Purchased | Answered			Q = 2 | Purchased		
Social Norm	$p=1$	$p=5$	Total	$p=1$	$p=5$	Total	$p=1$	$p=5$	Total
Neutral Frame	0.040	0.015	0.027	0.110	0.046	0.079	0.631	0.182	0.506
	(0.196)	(0.121)	(0.163)	(0.313)	(0.210)	0.270	(0.487)	(0.395)	(0.503)
	1427	1482	2909	520	475	995	57	22	79
Social Norm Low	0.048	0.016	0.032	0.174	0.055	0.112	0.667	0.320	0.577
	(0.215)	(0.127)	(0.176)	(0.379)	(0.230)	(0.316)	(0.475)	(0.476)	(0.496)
	1490	1528	3018	414	451	865	72	25	97
Social Norm High	0.055	0.024	0.039	0.158	0.073	0.115	0.538	0.333	0.474
	(0.230)	(0.154)	(0.195)	(0.366)	(0.260)	(0.320)	(0.502)	(0.478)	(0.501)
	1404	1484	2888	492	496	988	78	36	114
Total	0.0480	0.018	0.033	0.145	0.058	0.102	0.609	0.289	0.517
	(0.214)	(0.135)	(0.178)	(0.352)	(0.234)	(0.302)	(0.489)	(0.456)	(0.501)
	4321	4494	8815	1426	1422	2848	207	83	290

- A purchase rate of (**3%**) (**10%**) (un)conditional on answering the door
- Conditional on answering, the **extensive margin** corresponds to **15%** (**6%**) of total observations when *p*=1 (*p=5)*, respectively.
- Conditional on purchasing, the **intensive margin** corresponds to **60%** (**29%**) of total observations when *p*=1 (*p=5)*, respectively.

Reduced form: extensive margin

- We employ a simple linear probability model to estimate treatment effects on the likelihood to purchase conditional on answering the door.

Table 5: The Decision to Purchase Conditional on Answering Door: Linear Probability Model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Warning	0.028	0.046***					0.031*	0.047***	0.030*	0.047***
	(0.017)	(0.017)					(0.017)	(0.016)	(0.017)	(0.016)
Opt Out	0.015	0.021					0.013	0.017	0.012	0.017
	(0.018)	(0.015)					(0.017)	(0.015)	(0.017)	(0.015)
Social Norm Low			0.033*	-0.003			0.036**	0.005	0.063**	0.023
			(0.017)	(0.020)			(0.016)	(0.018)	(0.028)	(0.028)
Social Norm High			0.036**	0.030**			0.039**	0.038**	0.050*	0.053**
			(0.017)	(0.015)			(0.017)	(0.015)	(0.027)	(0.025)
Price					-0.087***	-0.083***	-0.089***	-0.085***	-0.065***	-0.064***
					(0.014)	(0.013)	(0.014)	(0.013)	(0.019)	(0.018)
Price*SNL									-0.053	-0.034
									(0.032)	(0.031)
Price*SNH									-0.022	-0.030
									(0.031)	(0.030)
Constant	0.087***	0.064***	0.079***	0.084***	0.145***	0.126***	0.107***	0.084***	0.096***	0.07***
	(0.012)	(0.028)	(0.010)	(0.030)	(0.012)	(0.026)	(0.016)	(0.029)	(0.018)	(0.032)
Surveyor Effects	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
City Effects	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
N	2848	2848	2848	2848	2848	2848	2848	2848	2848	2848

$*p < .1$; $**p < .05$; $***p < .01$

- Main results:

1. **Sorting:** Warning increases the likelihood of purchasing.
2. **Social norms:** the effect is positive, but there is no difference between H/L

Reduced form: intensive margin

- We employ a simple linear probability model to estimate treatment effects on the likelihood to purchase 2 packs against 1

Table 9: Decision to Purchase 2 Packages of CFLs Conditional on Purchasing: Linear Probability Model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Warning	0.121	0.092					0.121	0.072	0.125*	0.079
	(0.076)	(0.082)					(0.074)	(0.082)	(0.076)	(0.084)
Opt Out	0.086	0.137					0.112	0.173**	0.107	0.175**
	(0.085)	(0.093)					(0.082)	(0.086)	(0.082)	(0.086)
Social Norm Low			0.071	-0.052			0.073	-0.061	0.051	-0.068
			(0.082)	(0.104)			(0.074)	(0.095)	(0.088)	(0.106)
Social Norm High			-0.033	-0.080			-0.025	-0.081	-0.096	-0.155*
			(0.083)	(0.090)			(0.079)	(0.081)	(0.097)	(0.094)
Price					-0.320***	-0.322***	-0.314***	-0.328***	-0.437***	-0.420***
					(0.067)	(0.063)	(0.067)	(0.063)	(0.113)	(0.119)
Price*SNL									0.075	0.027
									(0.155)	(0.167)
Price*SNH									0.239	0.211
									(0.164)	(0.165)
Constant	0.443***	0.286***	0.506***	0.417***	0.609***	0.453***	0.511***	0.465***	0.545***	0.485***
	(0.055)	(0.168)	(0.062)	(0.197)	(0.038)	(0.150)	(0.082)	(0.189)	(0.089)	(0.195)
Surveyor Effects	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
City Effects	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
N	290	290	290	290	290	290	290	290	290	290

$*p < .1$; $**p < .05$; $***p < .01$

- Main results:

1. **Price** is highly significant while …
2. …**Social norms** are not.

Structural estimation: timing

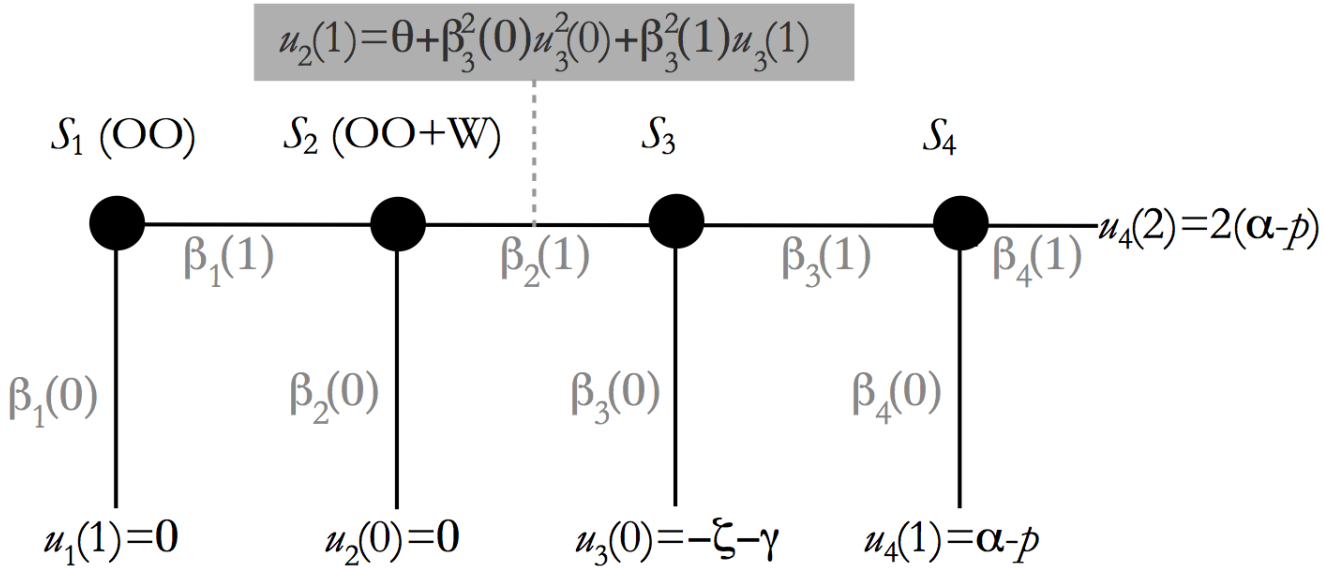


Figure 2: Timeline of the structural model

- **Stage 1**: checking the opt-out box (00).
- **Stage 2**: answering the door (OO+W)
- **Stage 3**: extensive margin decision (ALL)
- **Stage 4**: intensive margin (ALL)

Structural estimation: parameters

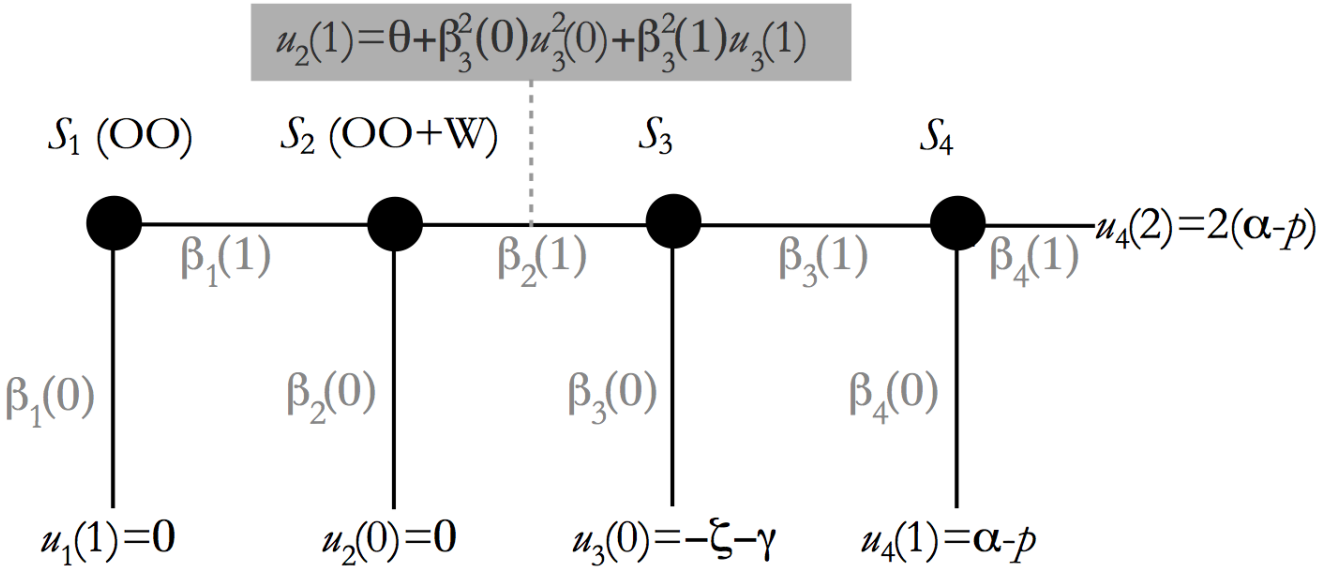


Figure 2: Timeline of the structural model

- The model is solved backward:
- **Stage 4**: **\alpha** measures (linear) WTP (efficiency, warm glow, …)
- **Stage 3**: **\zeta** and **\gamma** measure **social pressure** and **social norms**
- **Stage 2**: **\theta** measures **curiosity**
- We allow for the possibility of \theta and \zeta **to be correlated**

Structural estimation I: estimated parameters

- We estimate three different versions of the model, depending on whether we condition the estimation of \theta and \gamma to the extensive/intensive margin decision
- **Main results:**

1. **\alpha** is around $ 2
2. **\zeta** is negative, but not significant
3. **\theta** is negative and highly significant
4. **Social norms matter**, with H=L
5. **\zeta** and **\theta** are highly (negatively) correlated

Table 6: Structural estimations

	(1)	(2)	(3)
μ_α	2.327***	2.006***	1.381**
	(0.416)	(0.619)	(0.690)
β_L		0.799	
		(0.498)	
β_H		0.147	
		(0.732)	
β_W			1.362
			(0.882)
μ_ζ	-0.746	-0.318	0.623
	(0.702)	(0.808)	(0.997)
γ_L	0.214**	-0.916	0.216**
	(0.101)	(0.702)	(1.208)
γ_H	0.214**	0.014	0.209**
	(0.109)	(1.169)	(0.119)
γ_W			-1.97*
			(1.208)
μ_θ	-1.195*	-1.195*	-1.782*
	(0.694)	(0.691)	(0.915)
h_0	0.351***	0.349***	0.351***
	(0.011)	(0.008)	(0.011)
r	0.207***	0.207***	0.207***
	(0.019)	(0.019)	(0.019)
σ_α	4.810***	4.831***	4.774***
	(1.101)	(1.113)	(1.107)
σ_ζ	0.893***	0.901***	0.852***
	(0.222)	(0.232)	(0.262)
ρ	-0.9	-0.9	-0.9
	(-)	(-)	(-)
Obs.	8815	8815	8815
Log lik.	-7585.7101	-7584.158	-7583.371

Clustered standard errors. * $= p < .1$; ** $= p < .05$; *** $= p < .01$

Structural estimation II: heterogeneity

- Our structural model is such that the only stochastic components are attributed to **subjects' heterogeneity in the distribution of the behavioral parameters**.

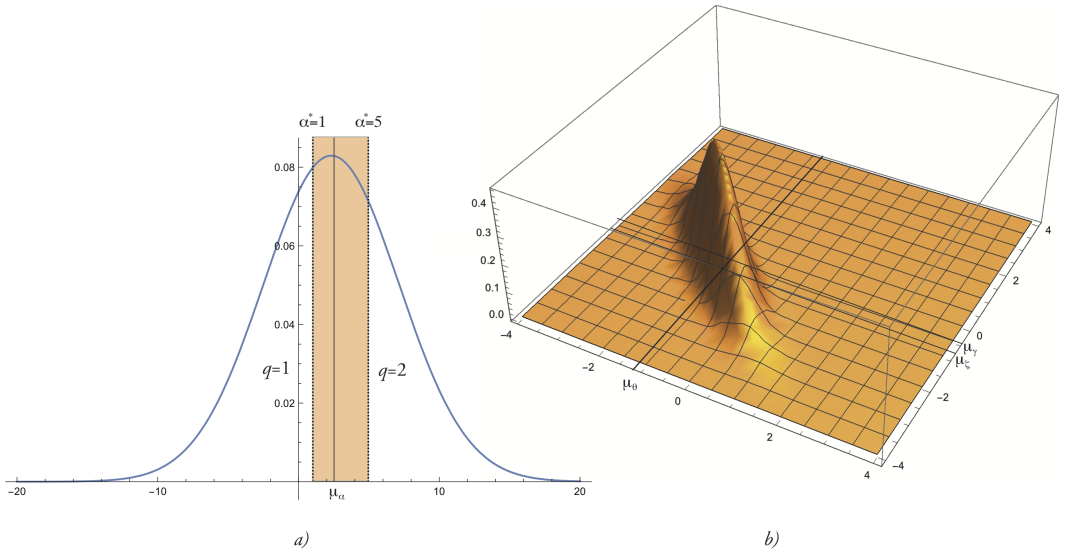


Figure 3: Estimated distributions of α, ς and θ (Model II).

- The correlation between curiosity and social pressure capture the sorting effect:

1. subjects with low curiosity sort out;
2. subjects with high curiosity sort in and are less sensitive to social pressure.

Structural estimation III: welfare analysis

- Our structural estimation allows to conduct welfare analysis.
- Welfare is measured as the variation in expected utility of the representativ agent due to the policy intervention.
- The **cost** of the intervention and the **benefits** on the electricity bill are not taken into account

Table 7: Welfare analysis

Warning	Social Norms	Price	(1)	(2)	(3)
No	No	1	0.719***	0.103	0.172
	No	5	0.261	-0.306	-0.219
No	Yes	1	0.728***	0.4***	0.181
	Yes	5	0.186	-0.149	-0.293
Yes	No	1	0.650***	0.468	0.251
	No	5	0.241	0.102	-0.111
Yes	Yes	1	0.662***	0.732***	0.234
	Yes	5	0.171	0.249	-0.183

Clustered standard errors. * $= p < .1$; ** $= p < .05$; *** $= p < .01$

- Main results:

1. Welfare effects are small […] and
2. significant only when the price is small

Concluding remarks

- **Heterogeneity** is important and can be exploit to make environmental policies more efficient

- In our structural model heterogeneity is entirely **unobservable** (debriefing quest data were too scarce to be useful).

- Additional relevant dimensions for future research:

1. **Beliefs** about energy savings
2. (Altruistic) **discounting**
3. **Risk/ambiguity** aversion

The End

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