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Using Sticks or Carrots to Promote Energy Efficiency – How do Individuals react?

Results of an Experimental Investigation

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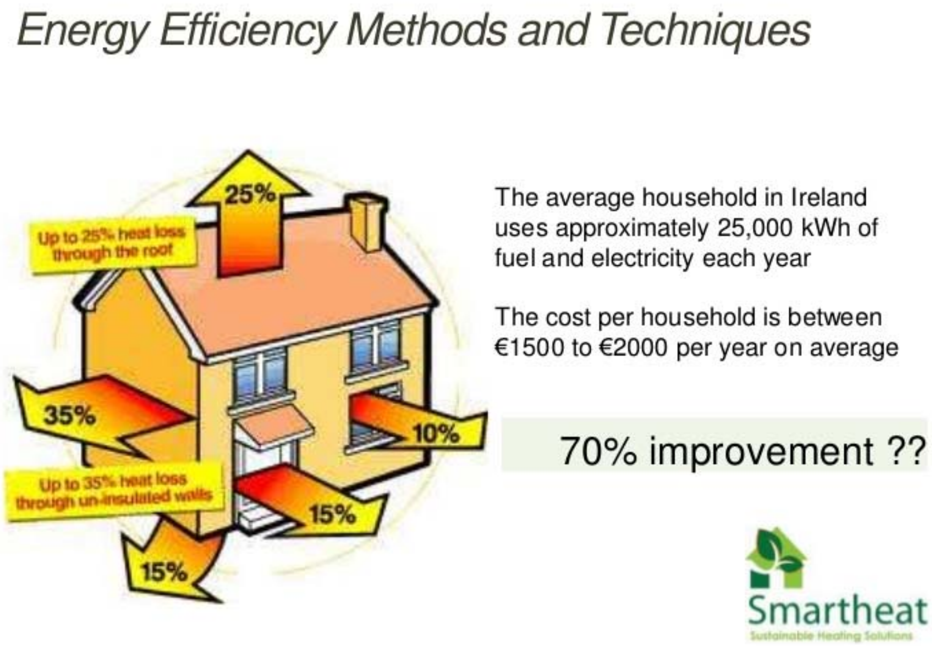
Contents

1 Motivation

- Energy efficiency: A major target of energy & environmental politics
- "energy efficiency gap" demands for government acitivities
- Energy efficiency investment decisions in economic literature:
  - Evaluation of programs via emission reductions & number of participants (Diefenbach et al. 2011)
  - Explanatory factors for individual investment decisions (Achtnicht & Madlener 2014, Alberini et al. 2013)
- Two aspects not considered in the literature thus far:
  1) Public good dimension: strategic aspects of individual behaviour
  2) Distributional issues (energy efficiency policy as a mean to overcome regressive effects of increasing energy prices?)

2 Model

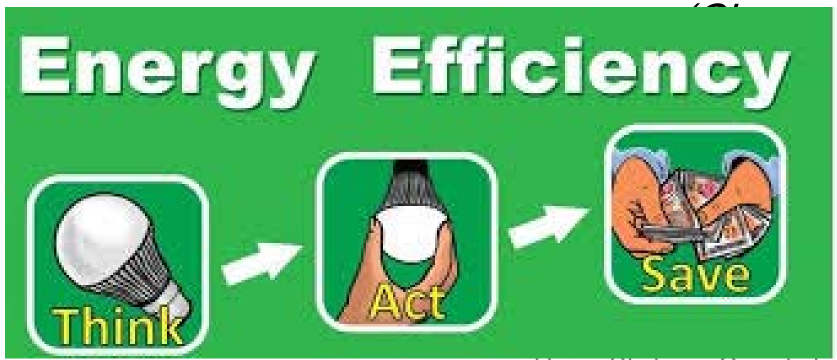


Individual perspective

- Investment in energ … (reduction of GHG)
- Impure public good
- Non-linear technolo

"All parties have diffe … t cost structures. This leads … n-linear. The key aspects … a … ze and cost structure) … and that … optimal allocation of resources almost certainly lies in the interior of the choice set."

(… al. 1999, p. 5).



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2 Model

- Individual perspective on energy efficiency investments ***I***
  - heterogeneous abatement cost curves
  - increasing cost/decreasing returns-principle
  - MPCR-calculation: not constant, depends on level of investment
  - Interior solutions: positive investments become optimal
  - Energy efficiency investments create positive external benefits (i.e. they reduce negative externalities from energy consumption)
  - $I_{Nash} << I_{Welfare}$: Social optimal investment exceeds optimal private investments

Research Question

- What helps society to stimulate social optimal investments?
- Sticks versus carrots: How do individuals react on policy instruments to internalize externalities?

2 Model

We focus on three implications of energy efficiency investments:

A) Investments (*I*) reduce consumption possibilities and constitute **opportunity costs**. Households are restricted in their investment decisions by their available budget.

B) Investments reduce energy expenditures and **generate savings**: The marginal saving of investments is positive and diminishing. Savings cannot exceed initial energy expenditures.

C) Investments improve the **environmen**t. All households of a society benefit from investments equally. Positive, diminishing marginal benefit. Environmental effect is negative below investments of a critical level.

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2 Model

Wage / endowment

Energy consumption = energy expenditures

Payoff-function :

$$\pi_i = [W_i - I_i] - \left[E_i * \left(1 - \gamma + \frac{\gamma}{e^{(\alpha * I_i)}}\right)\right] + \left[\sum_{j=1}^{n} \left(\left(I_j * S\right) - \left(\frac{(E_j * q) - S}{\theta * e^{(\theta * I_j)}}\right)\right)\right]$$

Household *i* is member of a society with *n* households: *i* ∈ { *j* = 1,…,*n* }
S, q, α, γ: paramter of a limited growth function π(*I*)

Effects of investments are decomposed into three summands:

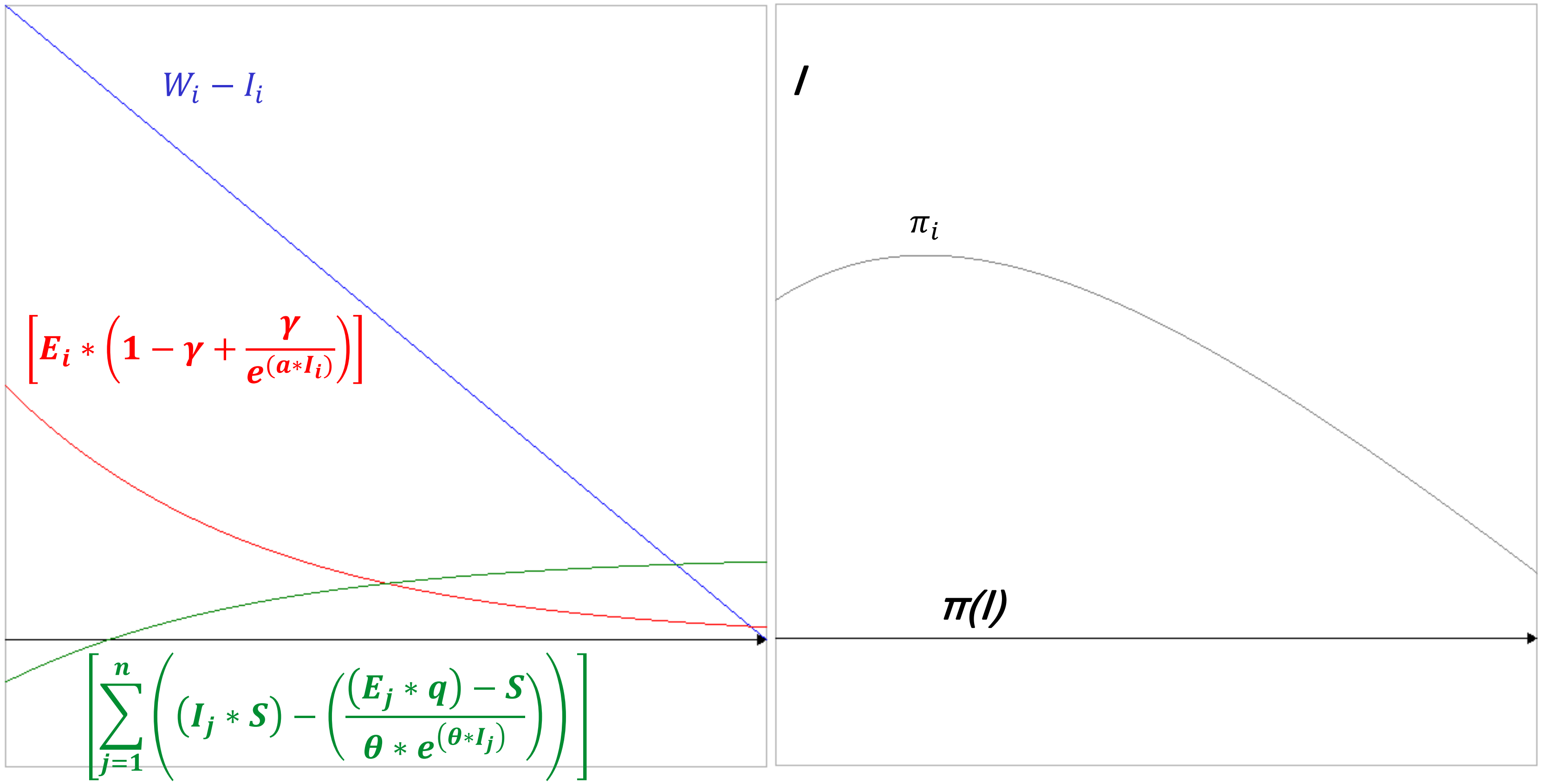
$[W_i - I_i]$ = Opportunity costs of investments (expenditures)

$\left[E_i * \left(1 - \gamma + \frac{\gamma}{e^{(\alpha * I_i)}}\right)\right]$ = Private benefits of investments (financial savings)

$\left[\sum_{j=1}^{n} \left(\left(I_j * S\right) - \left(\frac{(E_j * q) - S}{\theta * e^{(\theta * I_j)}}\right)\right)\right]$ = Public benefits of investments (environmental effect)

2 Model

Graphical Illustration of the payoff funciton:



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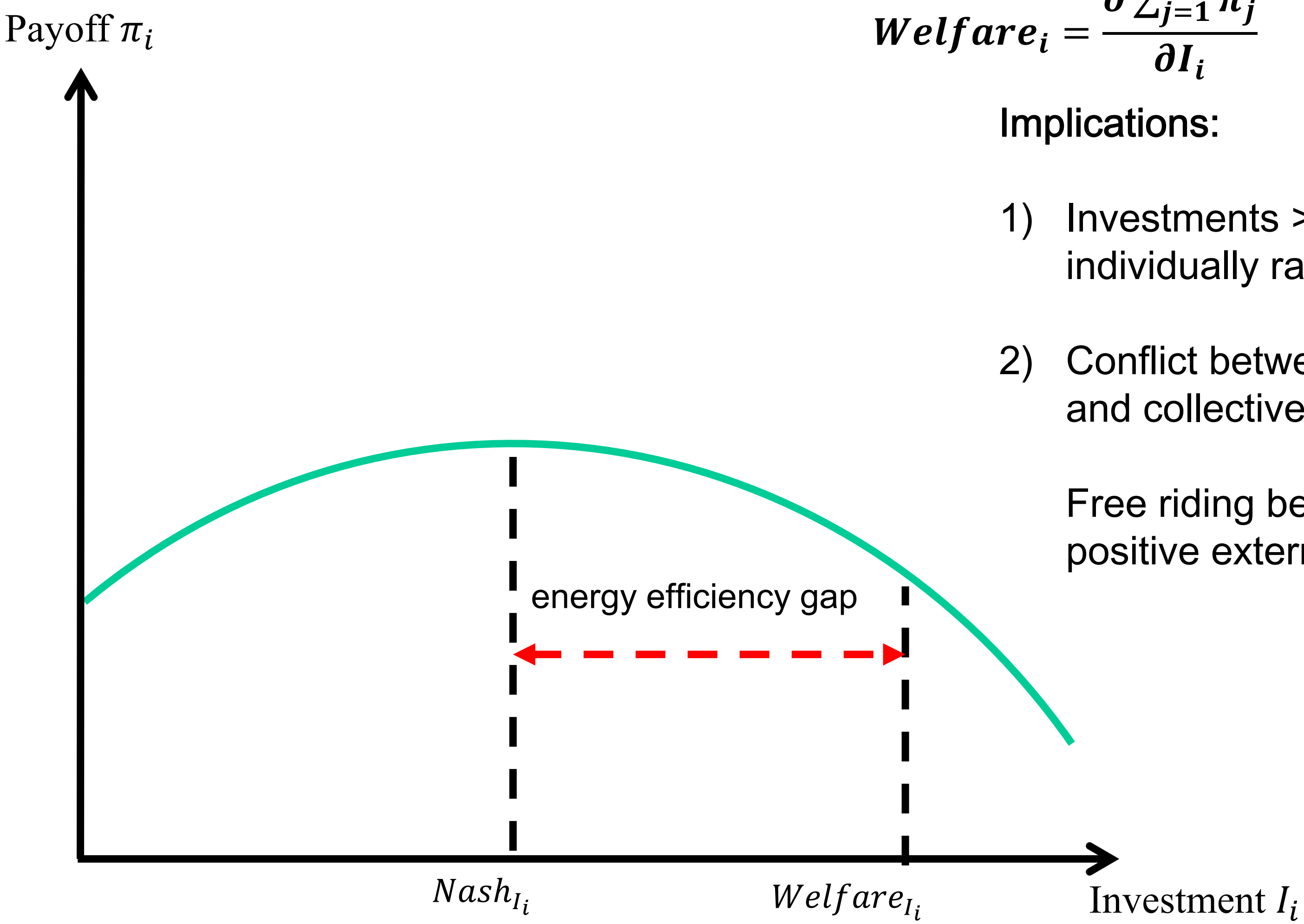
2 Model and Hypothesis

$$Nash_i : \frac{\partial \pi_i}{\partial I_i} = 0$$

$$Welfare_i = \frac{\partial \sum_{j=1}^{n} \pi_j}{\partial I_i}$$



Implications:

1) Investments > 0 are individually rational

2) Conflict between individual and collective rationality:

   Free riding because of positive externalities

2 Model: Sticks versus carrots

Subenvention of I or taxing of E are measures to internalize external effects

Subventions

- affect first summand of payoff-function
- paid for each unit of I bought (for a certain cap limit)
- Subventions reduce opportunity cost :

$$\boldsymbol{W_i} - (\boldsymbol{1} - \boldsymbol{f}) * \boldsymbol{I_i}; \quad 1 \geq f > 0$$

- Hypothesis: f gives rise to income effect, incentive effect is possible

Energy taxes

- affect second summand of payoff function
- increase financial savings :

$$(\boldsymbol{1} + \boldsymbol{t}) * \boldsymbol{E_i} * \left(\boldsymbol{1} - \boldsymbol{\gamma} + \frac{\boldsymbol{\gamma}}{\boldsymbol{e}^{(\boldsymbol{a} * \boldsymbol{I_i})}}\right); \qquad t > 0$$

- Hypothesis: t gives rise to income effect AND incentive effect

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3 Experimental Design

Experimental Setup:

- April 2017: Classroom experiment (lecture macroeconomics)
- 180 subjects adopt the role of households and make investment decisions
- 3 households form a hypothetical "society"
- heterogeneous household types in each society:

Household types				
Type	Income W_i	Energy consumption E_i	Disposable income D_i	Share of income needed to finance E_i
A	80	30	50	37.5%
B	100	35	65	35%
C	120	40	80	30%

- One-shot-decision: Every individual makes one incentivized investment decision
- Post-experimental questionnaire (soziodemographics and attitudes)
- Show-up fee (5 Euro) plus variable payoff (random lottery incentive mechanism)

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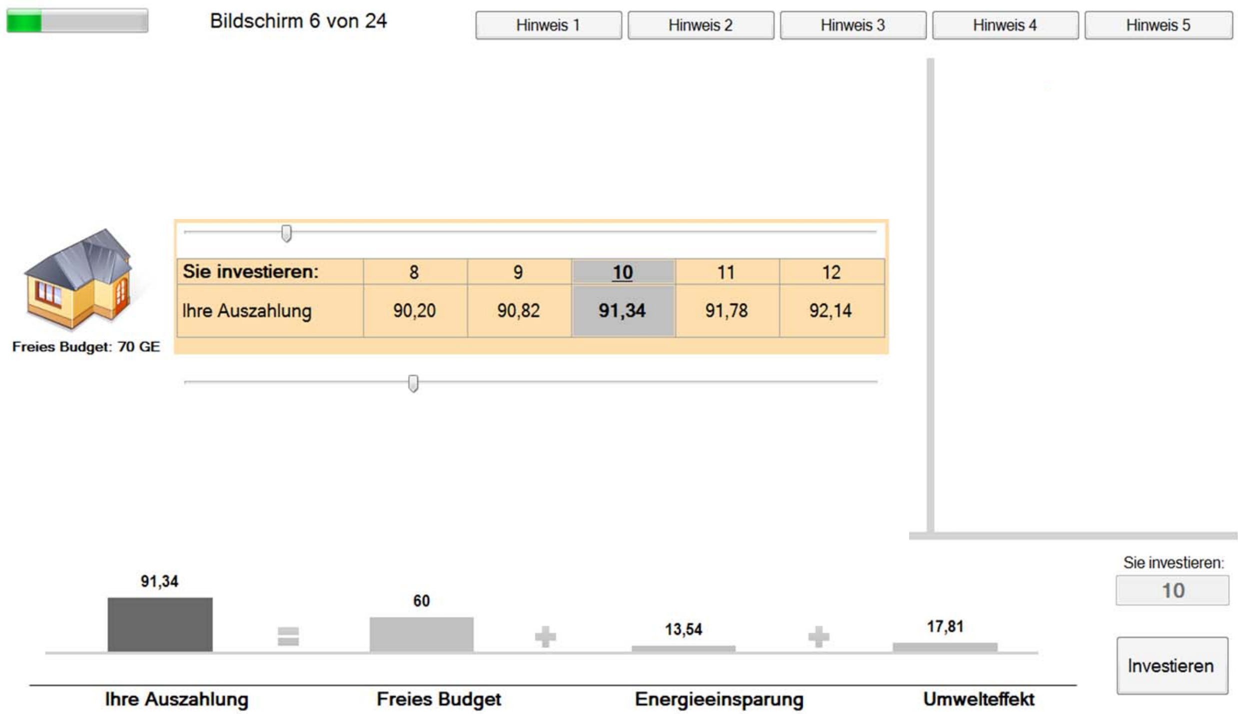
3 Experimental Design



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3 Experimental Design: Treatments

Between-Subjects-Design

- T1 (basic):
  - absence of intervention
- T2 (taxes):
  - Each household faces an additional energy tax on energy expenditure (t=0.5)
  - Total tax amount depends on investment
  - Tax revenue is redistributed in equal shares
- T3 (subvention_a)
  - Each household is paid a ring-fenced subvention G for his investment
  - The first 19 (A), 22 (B) and 26 (C) units are totally covered by a subvention
  - Total volume of subsidy payments is financed by the whole society
- T4 (subvention _b)
  - Each household is paid a ring-fenced subvention G for his investment
  - The first 15 (A), 18 (B) and 20 (C) units are totally covered by a subvention
  - Total volume of subsidy payments is financed by the whole society

4 Results

- Households and treatments

Treatment		Household	Hypotheses: Nash	Hypotheses: Welfare	Results: Median	Results: Modal	Results: Mean	I vs. Nash: p (Wilcoxon, 2-sided asymtotic sig.)
T1 (basic)		A (n=15)	15	50	15	15	17,27	0.562
		B (n=15)	18	65	20	18	29.60	**0.008***
		C (n=15)	20	80	22	20	31.87	**0.008***
T2 (tax)	t=0.5	A (n=15)	20	35	21	21	20.73	0.151
	t=0.5	B (n=15)	23	48	24	24	22.27	0.975
	t=0.5	C (n=15)	26	60	35	26	37.27	**0.009***
T3 (subvention_a)	G=19	A (n=15)	20	70	21	20	24.00	0..058
	G=22	B (n=15)	23	88	24	23	31.00	**0.033***
	G=26	C (n=15)	26	106	35	26	48.00	**0.003***
T4 (subvention_b)	G=15	A (n=15)	15	65	17	15	20.87	**0.011***
	G=18	B (n=15)	18	83	23	18	25.40	**0.003***
	G=20	C (n=15)	20	100	30	20	31.00	**0.046***

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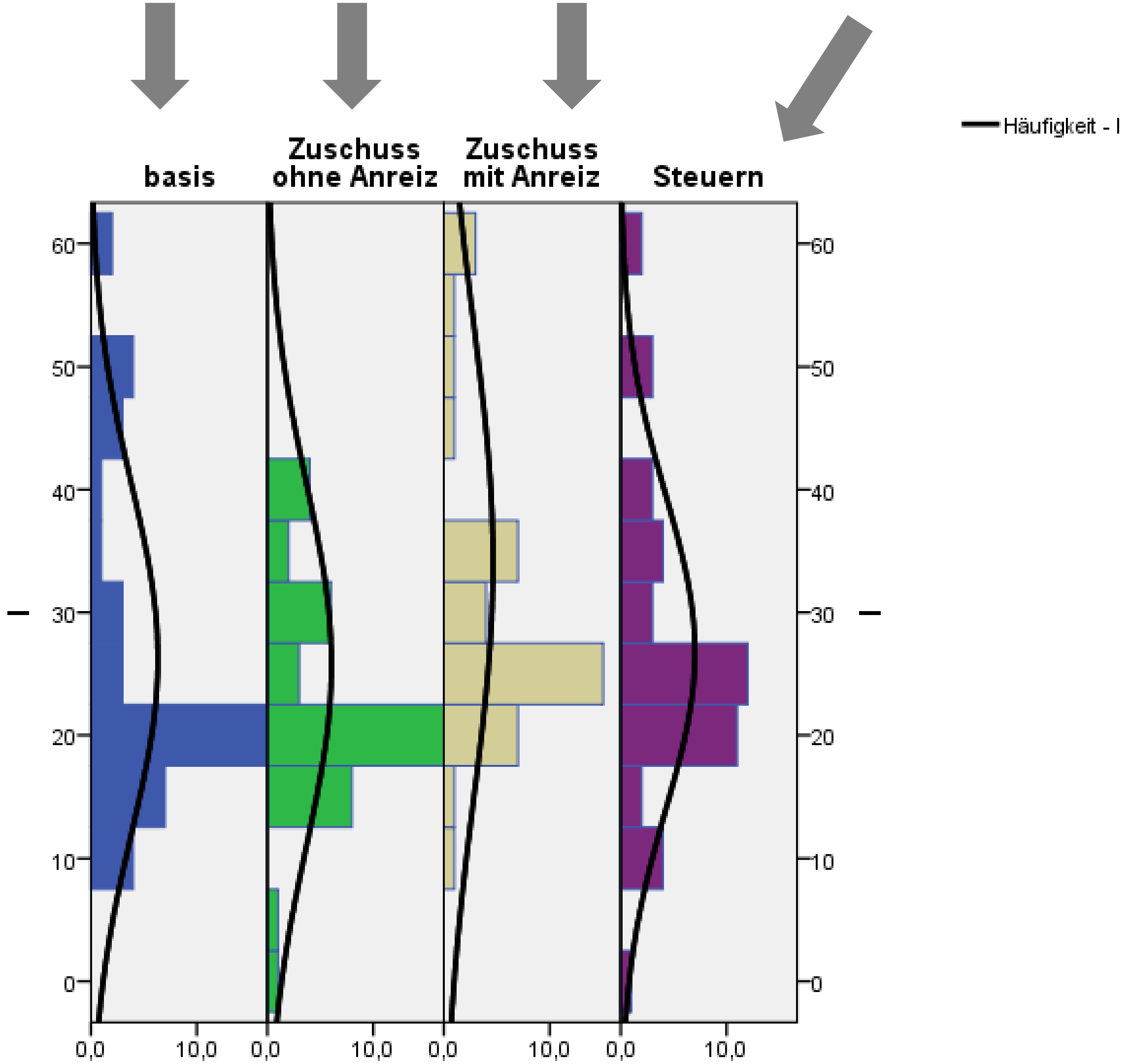
4 Results

Treat-ment	T1 (basic)	T4 (subvention_b)	T3 (subvention_a)	T2 (tax)
mean	26.24	25.76	34.16	26.76
median	20	21	26	24

- Treatment results (descriptive)



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4 Results

- Treatment results (descriptive)

Treat-ment	T1 (basic)	T2 (tax)	T3 (subvention_a)	T4 (subvention_b)
mean	26.24	26.76	34.16	25.76
median	20	24	26	21

- Treatment effects
  - Kolmogoroff-Smirnoff-Test
    - Z: Kolmogoroff-Smirnoff-Z
    - p: two-sided asymptotic sig.

	T1	T2	T3	T4
T1		Z=1.476 **p=0.026***	Z=2.003 **p=0.001***	Z=0.632 p=0.819
T2			Z=0.949 p=0.329	Z=1.034 p=0.216
T3				Z=1.897 **p=0.001***

4 Results

Reggression

- Household types and treatment variables
- Expectation of other individuals behaviour
- Reciprocity
- Interacts with policy variables (treatments)

	Model I		Model II		Model III		Model IV	
Variable	Coefficient	T-Value	Coefficient	T-Value	Coefficient	T-Value	Coefficient	T-Value
Constant	18.633***	7.297	-7.525**	-2.546	15.333***	7.141	22.545***	2.742
T2: Taxes	0.511	0.173	2.362	1.065	-19.556***	-3.932	-18.018**	-2.559
T3: Subvention_a	7.911***	2.683	5.203**	2.304	-19.447***	-3.981	-19.472**	-2.540
T4: Subvention_b	-0.489	-0.166	-1.007	-0.453	-20.632***	-4.300	-17.618***	-2.888
Houshold B	6.417**	2.513	11.276***	5.724	10.748***	4.926	8.345**	2.631
Household C	16.417***	6.429	23.948***	11.778	21.987***	9.757	21.338***	6.572
Exp. of other individuals I			0.409***	11.580				
Interaction T2_Exp					0.407***	4.616	0.383**	2.947
Interaction T3_Exp					0.450***	6.674	0.498***	4.004
Interaction T4_Exp					0.366***	4.878	0.338***	3.667
Acceptance Energy Policy							-1.900	-0.886
Cost to high							-1.595	-0.846
Model Summary	F=10.576 p(F)<0.001 R^2=0.233		F=38.579 p(F)<0.001 R^2=0.577		F=20.947 p(F)<0.001 R^2=0.499		F=8.124 p(F)<0.001 R^2=0.458	
Table Notes	Dependent variable: *I* [Euro]. Total n=180, significant coefficients are marked with one (two, three) asterisk(s) if p≤0.10 (p≤0.05, p≤0.01).							

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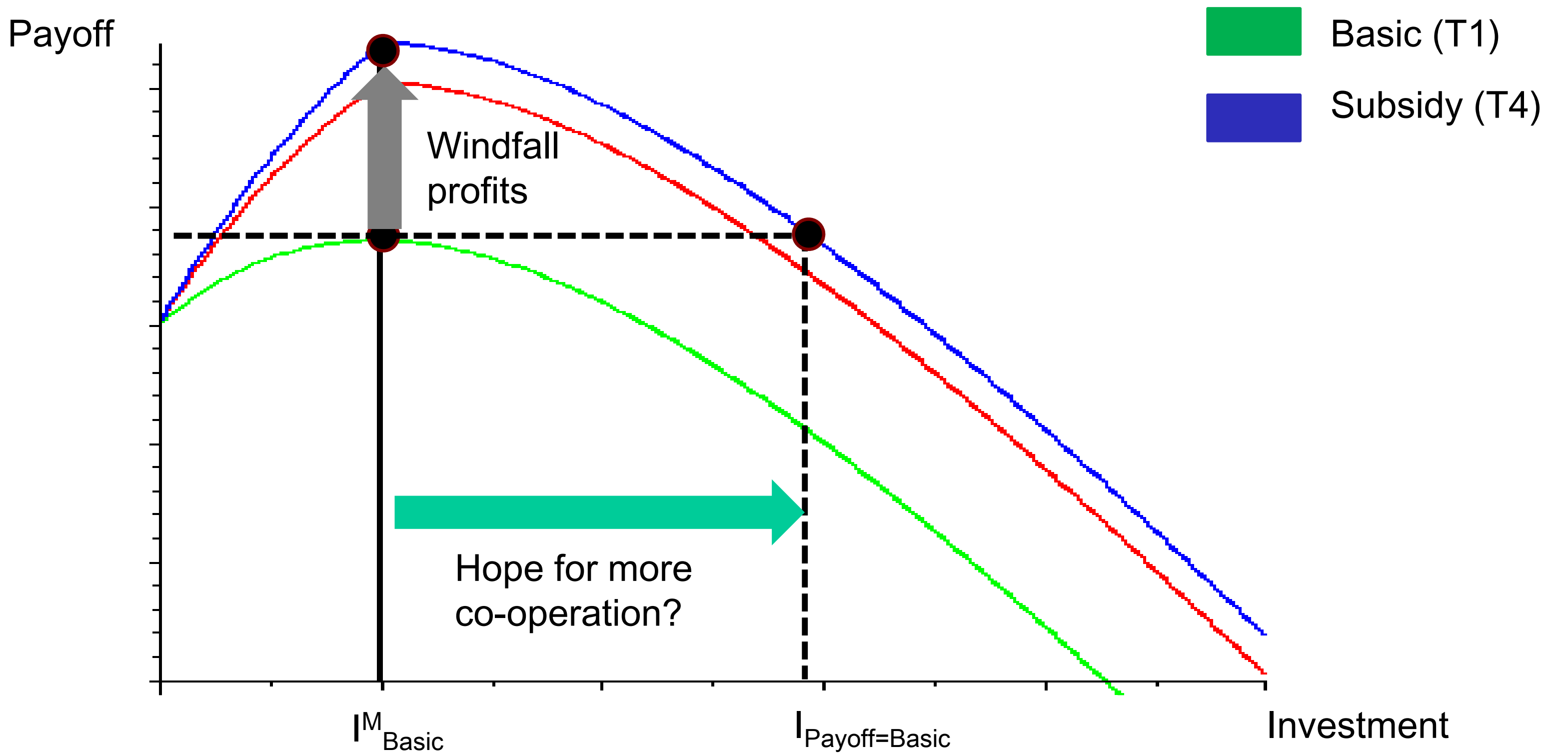
5 Conclusions

- Because of their regressive effects on the distribution of income energy taxes are not very popular as mean of energy policy
- Subsidy programmes as method of choice because they address two goals simultaneously:
  - subsidies attenuate negative social consequences of rising energy prices (especially for low incomome households)
  - and they also stimulate investments in energy efficiency.
- Results of the experiment: Taxes on energy consumption (T2) **and** subsidies for investments (T3) significantly stimulate individual investments (internalization of external effects)
- Paying subsidies for energy efficiency which only introduce positive income effects is not effective (T4):
  - Windfall gains: Reducing the opportunity costs of efficiency investments with the means of a subsidy does not necessarily motivate individuals to increase their investments
  - Reason: positive, but decreasing benefits are not affected

5 Conclusions

Income effect of subsidies (T4)



5 Conclusions

- Central question: How to prevent windfall profits as observed in T4?
  - **model and experimental design**: perfect information about the non-linear payoff function.
  - **Real-life**: details "behind" this payoff function are private information. Non-linearities include positive optimal investments for each household - even in the absence of sticks and carrots.
- If policy is not able to control the factors driving this optimal investment when fixing the subsidy, it is possible that subsidies fall flat.

➡ Facing the non-linearities of energy efficiency, energy taxes indubitably increase incentives to invest in efficiency, **even if policy has no information** about each households energy consumption characteristics.

➡ Positive role of **reciprocity**: efficiency campaigns and demonstration projects

Thank you for your attention!

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APPENDIX

4 Results

Treatments: Flat subsidy ("grant") for poorest household

$$\left(W_i - \boldsymbol{max(I_i - z_{iG}\, G, 0)} - \left(\boldsymbol{k_i \sum_{i=1}^{m} min(G, I_i)}\right)\right) - E_i\left(1 - \gamma + \frac{\gamma}{e^{(a*I_i)}}\right) + \sum_{i=1}^{n}\left(1 - \frac{\beta}{e^{(a*I_i)}}\right)\frac{E_i}{\varepsilon}; \qquad \boldsymbol{G = 10}$$

We assume that the costs caused by subsidies need to be financed by all households. Parameter $\boldsymbol{k_i}$ describes the share of costs a household needs to carry.

Treatment 3: egalitarian financing $\boldsymbol{k_i = \frac{1}{n} = \frac{1}{3}}$

Treatment 4: progressive financing $\boldsymbol{k_i = \frac{W_i}{\sum W_i}}$

Model variants

Taxes (T2): $$\left(\ldots + \boldsymbol{k_i}\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}}\left((\boldsymbol{1}+\boldsymbol{z_{it}t})\boldsymbol{E_i}*\left(-\boldsymbol{\gamma}+\frac{\boldsymbol{\gamma}}{e^{(a*I_i)}}\right)\right)\right)-(\boldsymbol{1}+\boldsymbol{z_{it}t})E_i\left(1-\gamma+\frac{\gamma}{e^{(a*I_i)}}\right)+\sum_{i=1}^{n}\left(1-\frac{\beta}{e^{(a*I_i)}}\right)\frac{E_i}{\varepsilon}$$

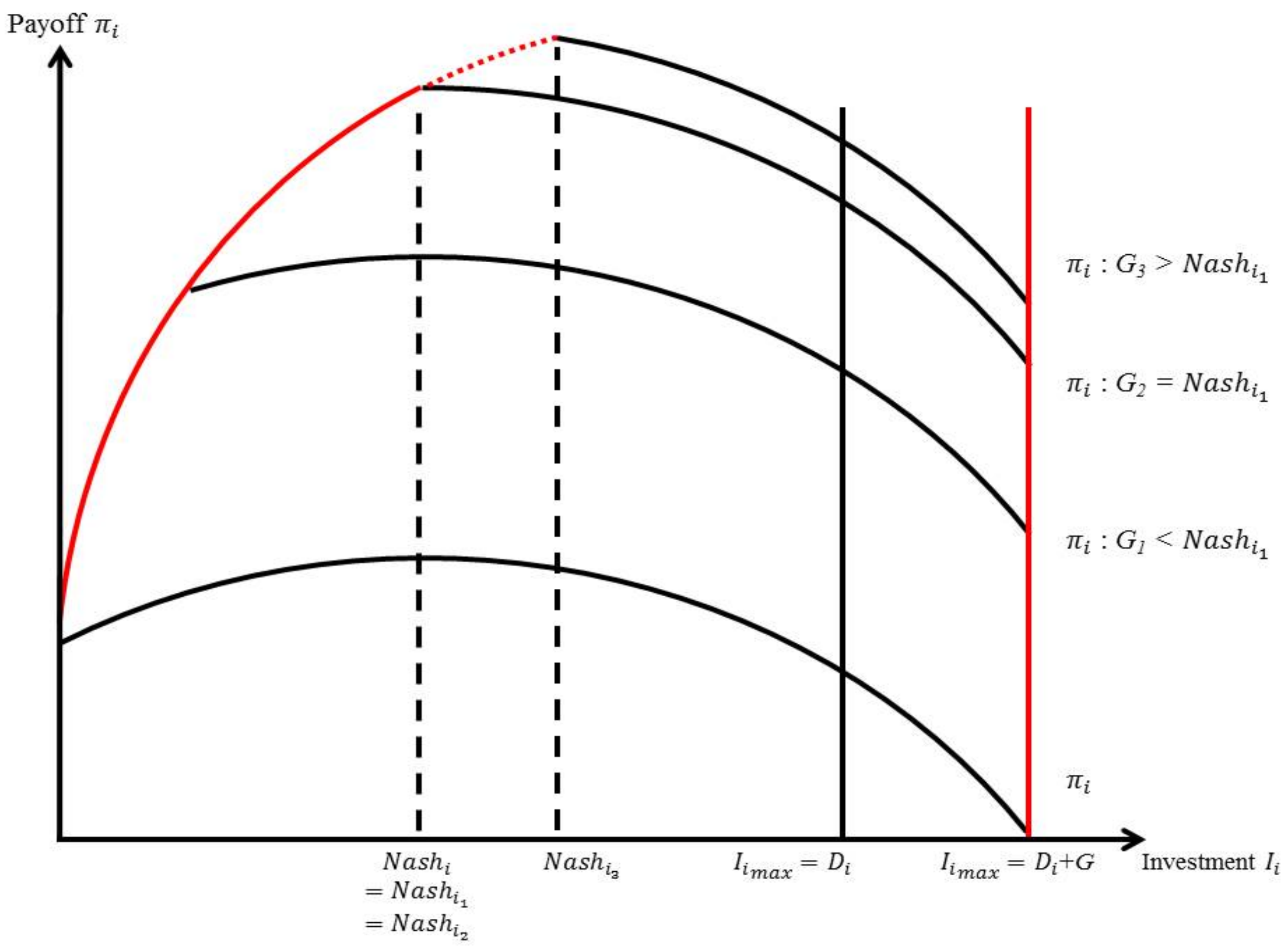
Subsidies T3+T4: $$\left(W_i-\boldsymbol{max(I_i - z_{iG}\, G, 0)}-\left(\boldsymbol{k_i}*\boldsymbol{f}\sum_{\boldsymbol{i=1}}^{\boldsymbol{m}}\boldsymbol{min(G, I_i)}\right)\right)-E_i\left(1-\gamma+\frac{\gamma}{e^{(a*I_i)}}\right)+\sum_{i=1}^{n}\left(1-\frac{\beta}{e^{(a*I_i)}}\right)\frac{E_i}{\varepsilon}$$

Loans: $$\left(W_i-(\boldsymbol{1}-\boldsymbol{f}*\boldsymbol{z_{if}})I_i-\left(\boldsymbol{k_i}*\sum_{\boldsymbol{i=1}}^{\boldsymbol{m}}(\boldsymbol{I_i})\right)\right)-E_i\left(1-\gamma+\frac{\gamma}{e^{(a*I_i)}}\right)+\sum_{i=1}^{n}\left(1-\frac{\beta}{e^{(a*I_i)}}\right)\frac{E_i}{\varepsilon}$$

Obligations: $$(W_i-\mathbf{min}(\boldsymbol{O}*\boldsymbol{z_{iO}},\boldsymbol{I_i}))-E_i\left(1-\gamma+\frac{\gamma}{e^{(a*\mathbf{min}(\boldsymbol{O}*\boldsymbol{z_{iO}},\boldsymbol{I_i}))}}\right)+\sum_{i=1}^{n}\left(1-\frac{\beta}{e^{(a*\mathbf{min}(\boldsymbol{O}*\boldsymbol{z_{iO}},\boldsymbol{I_i}))}}\right)\frac{E_i}{\varepsilon}$$

Parameters: $t \in [0,1]$; tax rate. $f \in [0,1]$; rate of cost reduction through government loan. $G > 0$; height of government grant. $O > 0$; investment obligation. $m \leq n$ is the number of households included in a policy. $z_{it} \in \{0,1\}$; discrete variable displaying whether household i is required to pay energy taxes.$z_{iG} \in \{0,1\}$; discrete variable displaying whether household i is entitled to receive grants. $z_{if} \in \{0,1\}$; discrete variable displaying whether household i is entitled to receive loans. $z_{iO} \in \{0,1\}$; discrete variable displaying whether household i is required to fulfil investment obligations.

Nash-solutions and grants



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Hinweis 1 | Hinweis 2 | Hinweis 3 | Hinweis 4 | Hinweis 5

So wirkt Haushalt A auf Ihre Auszahlung:

Haushalt A investiert:	28	29	**30**		
Ihre Auszahlung	91,13	91,24	**91,34**		

Freies Budget: 70 GE

Sie investieren:	8	9	**10**	11	12
Ihre Auszahlung	90,20	90,82	**91,34**	91,78	92,14

So wirkt Haushalt C auf Ihre Auszahlung:

Haushalt C investiert:	34	35	**36**	37	38
Ihre Auszahlung	91,05	91,20	**91,34**	91,48	91,60

Auszahlung Haushalt A: 34,5 GE

Ihre Auszahlung: 91,34 GE

Auszahlung Haushalt C: 127,2 GE

Summe: 253,04 GE

Sie investieren: 10

Investieren

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