Energy efficiency for low-income households: What about rebound effects?

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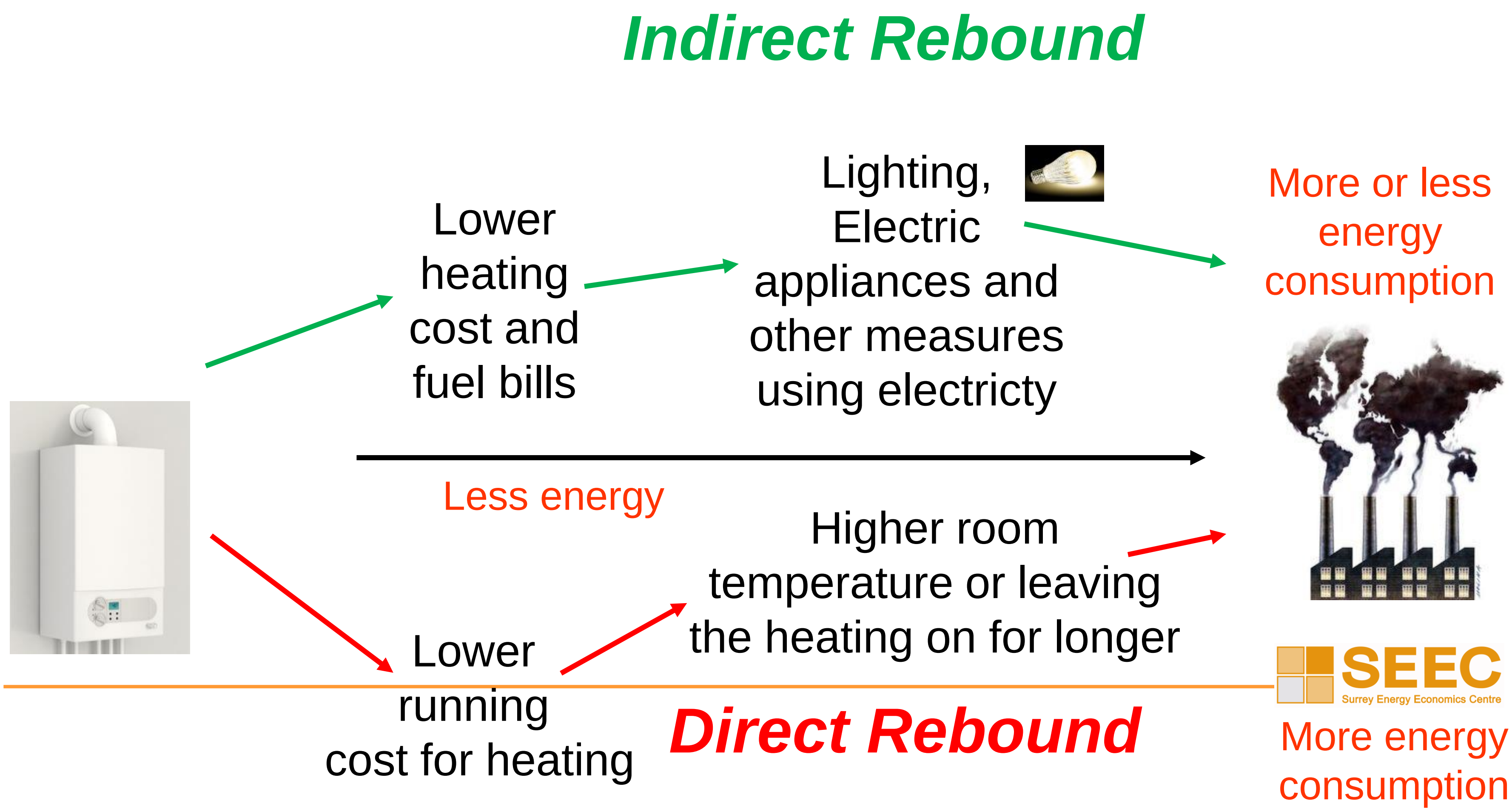
Introduction

- Households are encouraged to improve energy efficiency measures at home to save energy consumption and energy bills.
- However, the expected reduction in energy consumption might not be achieved due to ‘rebound effects’.
- It is expected that lower income households have larger rebound effects.
- This study estimates the rebound effects for heating service for Metsovo (Greece).

Rebound mechanisms for households

Total Rebound=Direct Rebound+Indirect Rebound



Data

- Metsovo
  - Mountainous area in Greece
  - 890 households
  - Cold weather
    - implying the great thermal energy needs of the buildings in the area.
  - 81% of homes were built before 1980, only 5% were built in the last 20 years.
  - The first Insulation Regulation in Greece was implemented in 1980
    - the lack of basic insulation standards is a major problem in Metsovo.
  - Heating systems are mostly old
  - Main fuel for heating is diesel oil and firewood

Data

- Data was collected through a questionnaire survey as part of the “STEP-IN—Using Living Labs to roll out Sustainable Strategies for Energy Poor Individuals” project (https://www.step-in-project.eu/)
- Survey was carried out between November 2020 and January 2021 (during covid restrictions)
- In total, 303 households participated in the survey through personal interviews
- The questionnaire collected information about housing conditions, type of heating systems, energy usage and expenditure, indicators of energy poverty, attitudes and behaviours towards energy efficiency and typical sociodemographic data.

Data

Summary statistics for Metsovo survey

Variable description (unit)	Variable name	Mean	Standard Deviation	Minimum	Maximum
Heating expenditure (€)	*heat_exp*	2013.10	893.38	400	5000
Electricity expenditure (€)	*elec_exp*	893.84	424.23	70	4000
Heating fuel price (€/KWh)	*fuel_price*	0.054	0.027	0.02	0.083
Heating service price (€)	*heat_price*	0.07	0.03	0.03	0.10
Heating efficiency (%)	*heat_eff*	79.66	15.02	20.26	100
Income	*income*	16560.16	8607.38	3000	35000
Dwelling size (m^2)	*dw_size*	98.71	29.07	40	250
Heating hours (hours)	*heat_hrs*	3.69	0.6	1	4
Dwelling age (years)	*dw_age*	45.60	29.81	3	320
Household size (number)	*house_size*	2.96	1.47	1	8
Age of household reference person (years)	*age*	50.89	16.65	18	102
Dummy for dwelling type (Ddw=0 for detached house, D=1 otherwise)	*Ddw*	0.63	0.48	0	1
Dummy for household reference person gender (Df=0 for male, Df=1 for female)	*Df*	0.35	0.48	0	1

Methodology

- **Heating service demand** *incorporating **'efficiency'** of heating service through the price of heating service* (OLS robust standard errors):

$$\ln h_i = \alpha + \beta \ln p_i + \gamma \ln x_i + \lambda \ln dsize_i + \theta \ln dage_i + \varphi \ln hrs_i + \tau \ln hsize_i$$
$$+ \omega \ln age_i + \rho Dd_i + \xi Df_i + \upsilon_i$$

Where *h*: expenditure for heating service, *p*: the price of heating service, *x*: the disposable income, *dsize* is dwelling size, *dage*: dwelling age , *hrs*: heating hours, *hsize*: household size, *age*: household reference person age, *Dd*: dummy for dwelling type, *Df*: dummy for household reference person gender, υ is an error term and *i* represents household. ***p = pf/ε*** where p_f is the price of heating fuel and ε is the heating efficiency of the household heating system.

- **Electricity service demand** (SFA)

$$\ln el_i = \alpha' + \beta' \ln p_i + \gamma' \ln x_i + \lambda' \ln dsize_i + \tau' \ln hsize_i + \omega' \ln age_i + \xi' Df_i + \upsilon'_i - u_i$$

Where *el:* expenditure for electricity service, υ': the error term, ***u:* the inefficiency term**

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Direct rebound

Direct rebound effect:

(-)
$own\ price\ elasticity\ of\ heating\ service\ (quantity)$
$= own\ price\ elsticity\ of\ heating\ service\ (expenditure) - 1$

Direct rebound effect for heating = 48%

Balezentis et al. (2021) estimated a direct rebound of 32% for Greece national level. Our results confirm that rebound effect for lower income groups is higher.

$$\mathrm{Rd} = -\eta_{q_h, p_h}$$

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

All variables, except dummy variables, are in natural logarithm.

OLS (robust standard errors) estimated results for heating service demand in Metsovo

Variables	lheat_exp
lheat_price	0.5207***
	(0.0695)
lincome	0.1312**
	(0.0639)
ldw_size	0.3433***
	(0.0951)
lheat_hrs	0.2582*
	(0.1320)
ldw_age	0.0381
	(0.0535)
lhouse_size	0.1365**
	(0.0603)
lage	0.1498*
	(0.0850)
Ddw	-0.0522
	(0.0582)
Df	0.1699***
	(0.0615)
Constant	7.3221***
	(1.0285)
Observations	211
R-squared	0.3434

Indirect rebound

Indirect rebound effect from improved efficiency of heating service is determined by the cross-price elasticity of electricity service demand in terms of quantity.

$$R_{id} = -(\frac{q_{el}}{q_h})\eta_{q_{el},p_h}$$

Indirect rebound effect for electricity service = -0.91%

Total rebound effect = 47.1%

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

All variables, except dummy variables, are in natural logarithm.

Estimated stochastic frontier model for electricity service demand in Metsovo

VARIABLES	Lel-exp
lheat_price	0.0755
	(0.0671)
lincome	0.1707***
	(0.0617)
ldw_size	0.1780**
	(0.0896)
lhouse_size	0.1845***
	(0.0598)
lage	-0.1653**
	(0.0812)
Df	-0.0039
	(0.0601)
Constant	5.6390***
	(1.0177)
sigma_v	0.2874
sigma_u	0.4303
lambda	1.4974
Observations	210

SFA efficiency scores

Summary statistics for estimated technical efficiency scores for electricity in Metsovo

Mean	Standard deviation	Minimum	Maximum	Observations
0.7352	0.1087	0.1585	0.9313	210

Efficiency scores are calculated as efficiency=exp(-$\hat{u}$).

- Inefficiency represents both inefficiency from appliances and the improper use of appliances such as management or behaviours.
  - e.g. household leaving the light on when not in the room.
- Since the overall energy efficiency of electricity services in Metsovo sample is relatively high it is quite likely that most of the inefficiency comes from household habits and behaviours.

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Discussion

- No backfire, but rebound is not negligible
  - Direct rebound plays a significant role
- Indirect rebound of non-energy goods is neglected
- Mitigating rebound effects and fuel poverty issues
- Rebound effect is not necessarily a bad thing for low-income households
- But be aware that all the expected reduction in energy consumption might not be achieved!

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