Direct and Indirect Rebound Effects for Residential Heating in Switzerland

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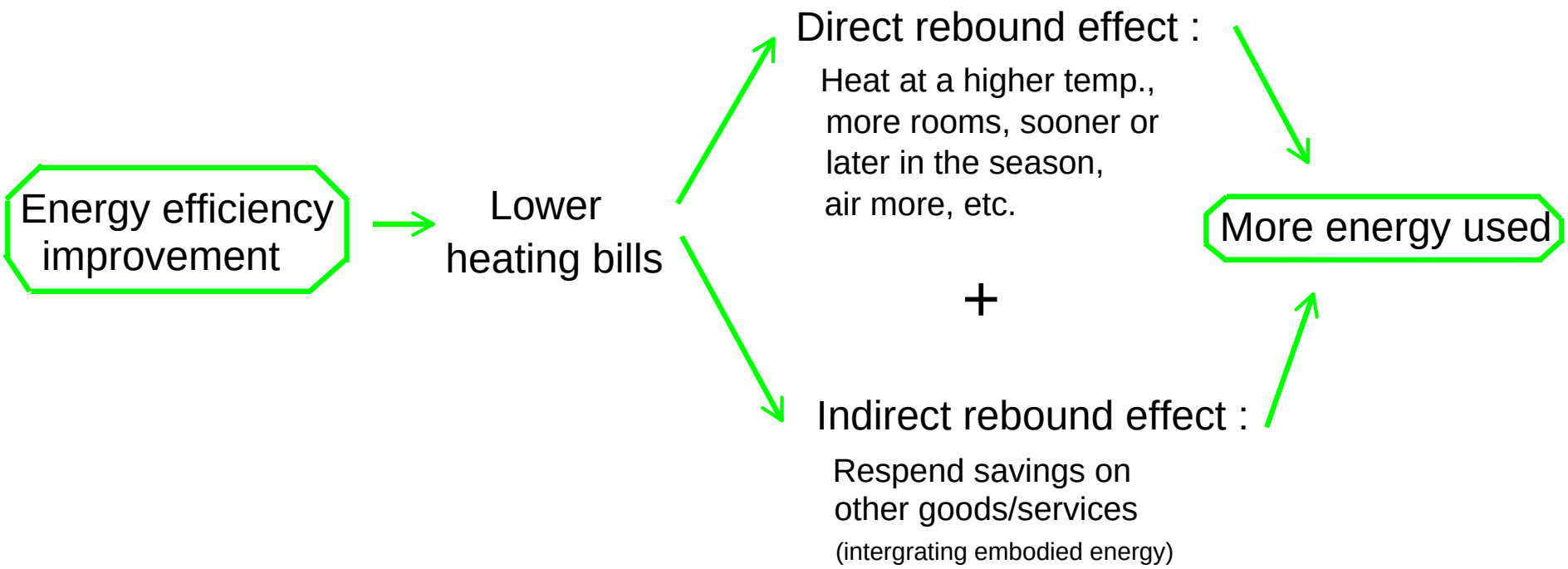
What are the direct and indirect rebound effects (RE)



Motivation

- 30% of primary energy consumption is attributable to heating, air-conditioning and hot water in buildings
- Promoting energy efficiency is the first pillar of the *energy strategy 2050* in Switzerland
  - 4 sectors targeted: buildings in first position, then mobility, industry and appliances
- But little is known about the household's reaction, and very few datasets to estimate both the direct and indirect REs.

Data

Microeconomic data:

- Online survey with 3,555 respondents representative of Swiss population
- To measure direct and indirect REs:
  1. A contingent behaviour model, with hypothetical scenarios (stated preferences)
  2. Data on heating costs, characteristics of the house, heating behaviours (revealed preferences)
  3. Spending patterns and hypothetical respending exercise (for the indirect RE)

Results with the stated preferences

- A direct RE of about 10-15%
  - In a literature review: 10-30% (Sorrel, 2009), 10% (Nadel, 2016)
- An indirect RE of about 25%
  - In a literature review: 10-20% (Nadel, 2016)
- Large heterogeneity in the magnitude of the direct RE (about 50% of people do not rebound)

Now: Estimate REs with revealed preferences

Model

- System of equations to account for the endogeneity of efficiency and heating usage:

$$\begin{cases} \text{Ln(heating efficiency) = f (heating costs and household characteristics)} \\ \text{Ln(heating costs) = g (heating efficiency and household characteristics)} \\ \text{Ln(embodied energy of spendings) = h (heating eff. and household char.)} \end{cases}$$

- $Direct\,RE = 1 + \frac{\partial ln(costs)}{\partial ln(efficiency)}$ and $Indirect\,RE = \frac{\partial ln(embodied\,energy)}{\partial ln(efficiency)}$

- Efficiency: $\varepsilon = \frac{m^2 * temp}{costs}$ ▸ efficiency

  Defined by its inverse cost intensity with a behavioural adjustment

- Heating costs: self-reported for a 1-year period (N=1,699) ▸ h.costs

  CHF 1,100 on average, CHF 1,300 in the Swiss household budget survey

3SLS

- At least one instrument per equation:
  - For efficiency: construction year (in decade)
  - For heating costs: hh size and a dummy for winter 2014 or 2015
  - For the embodied energy of spendings: number of cars (or number of flights)
- Hh characteristics: tenant, income, education, temperature (<19.5; 19.5-22.5; >22.5), environmental attitudes
- House characteristics: housing type, m^2, region, heating fuel

First Equation

	Ln(eff)
Ln(costs)	3.021***
	(1.112)
Years 1920	−0.511
	(0.238)**
Years 1930	−0.538*
	(0.288)
Years 1940	0.398
	(0.268)
Years 1950	0.029
	(0.189)
Years 1960	0.296
	(0.202)
Years 1970	0.459**
	(0.217)
Years 1980	0.253
	(0.172)
Years 1990	1.233***
	(0.435)
Years 2000	1.609***
	(0.508)
Years 2010	1.422***
	(0.463)
Hh and house characteristics	YES
Constant	−21.159***
	(7.794)
N	1,082

Second Equation

	Ln(costs)
Ln(efficiency)	-0.826^{***}
	(0.0455)
Hh size	0.029^{***}
	(0.007)
Winter 2015	0.036^{**}
	(0.018)
m^2	0.004^{***}
	(0.000)
19.5-22.5 degrees	0.187^{***}
	(0.028)
>22.5 degrees	0.278^{***}
	(0.034)
Education	-0.009^{**}
	(0.004)
Income	0.048^{***}
	(0.007)
Tenant	-0.115^{***}
	(0.024)
Hh and house characteristics	YES
Constant	6.799^{***}
	(0.071)
N	1,082

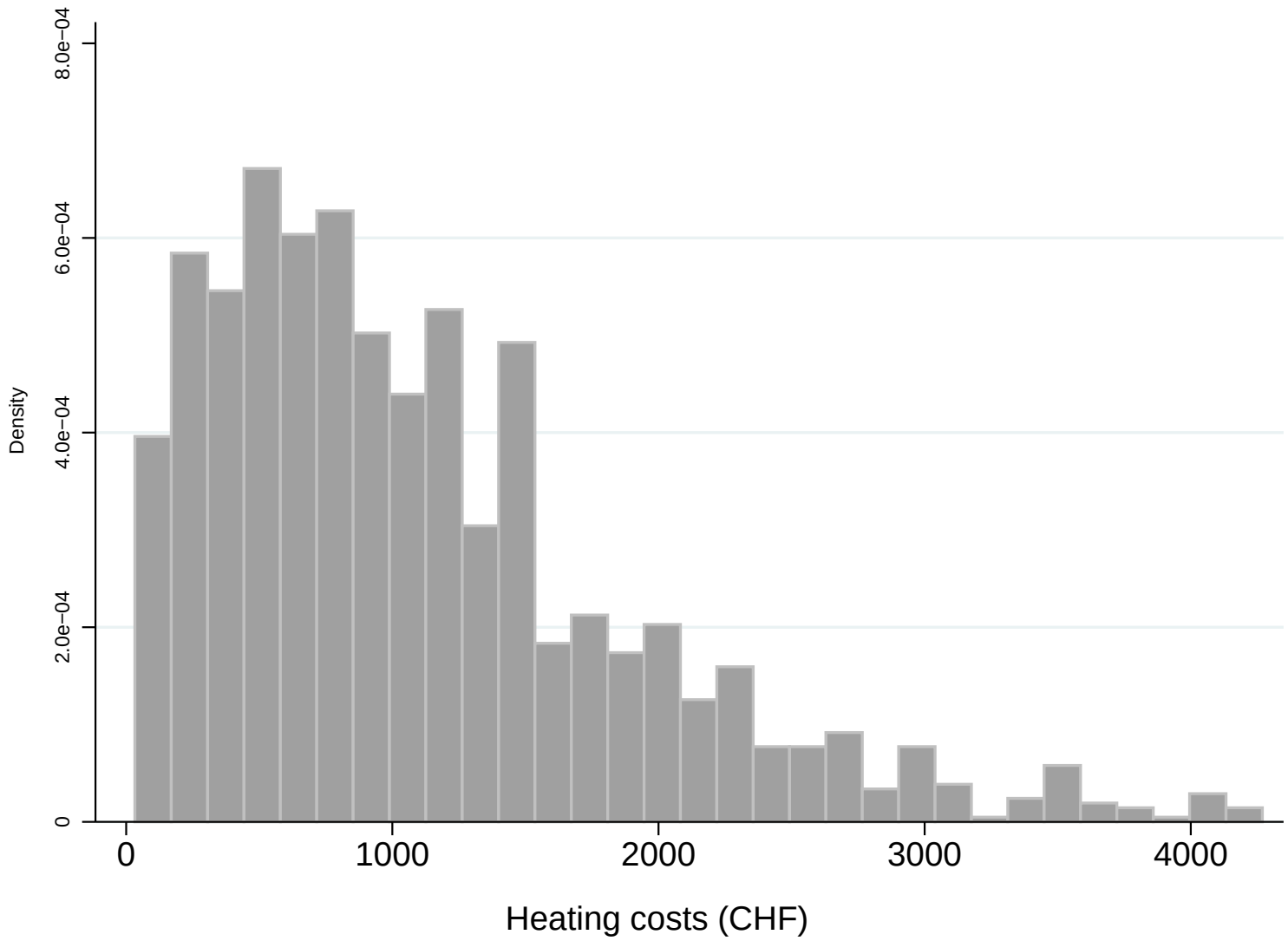
Third Equation

	Ln(kwh of spendings)
Ln(efficiency)	0.305^{***}
	(0.079)
Number of cars	0.059^{**}
	(0.027)
Environmental Attitudes	-0.006^{**}
	(0.003)
Education	0.162^{***}
	(0.016)
Income	0.026^{**}
	(0.011)
Hh and house characteristics	YES
Constant	8.203^{***}
	(0.168)
N	1,082

Conclusion

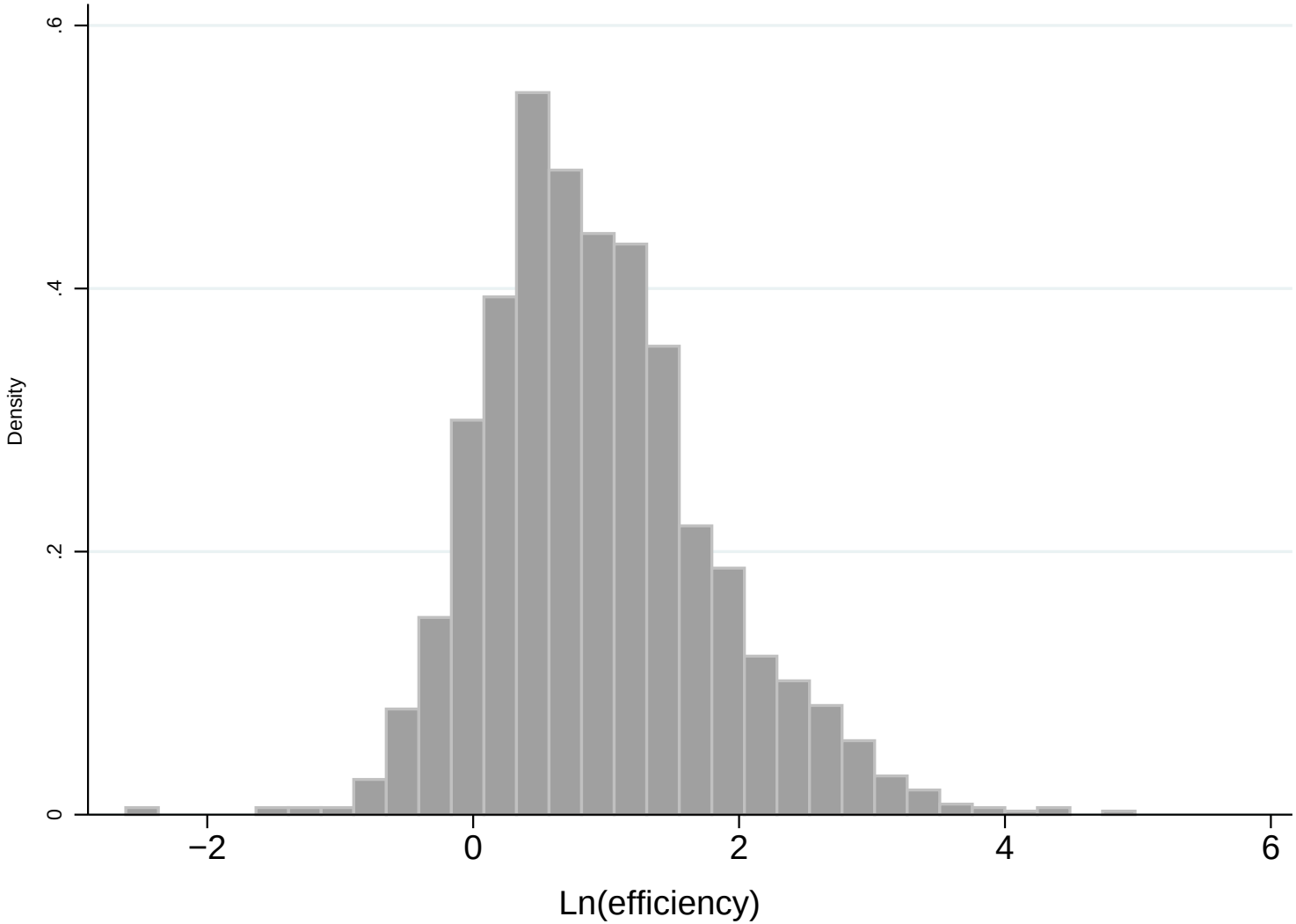
- A direct RE of about 17%, and an indirect RE of about 30%
  → Almost half of the expected energy savings are not realised because of the direct and indirect rebound effects.
- In the range (slightly higher) of our previous estimations based on stated preferences
- Without the 3SLS (simply OLS), both rebound effects are under-estimated

Heating costs



Return1

Efficiency



Return2