Explaining electricity demand and the role of energy and investment literacy on end-use efficiency of Swiss households

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Motivation

- Energy efficiency has been a part of the strategy of many industrialized nations to
  - reduce CO_2 emissions and air pollution
  - increasing security of energy supply
- 30-40% of end-use electricity consumption in OECD countries from households.
- Inefficiency in the use of energy may be due to
  - Low adoption of new energy-efficient technologies
  - Inefficient use of e.g. electrical appliances
- Caused by:
  - Market failures
  - Behavioural failures e.g. bounded rationality

Research questions

1. Measure the level of efficiency in the use of energy (electricity)
2. Identifying what drives the differences in the level of energy efficiency among Swiss households
   - role of energy literacy
   - role of investment literacy

⇒ In order to answer these questions we use stochastic frontier analysis

Previous work – residential energy efficiency

- Empirical measurement with aggregated data:
  - Filippini and Hunt (2012)
  - Zhou et al. (2012)
  - Filippini et al. (2014)
  - Filippini and Zhang (2016)
  - ...
- Empirical measurement with disaggregated data:
  - Weyman-Jones et al. (2015)
  - Alberini and Filippini (2015)
  - Boogen (2017)

Previous work – energy and investment literacy

- Energy literacy (DeWaters and Powers, 2011)
  - knowledge about energy production and consumption
  - attitudes and values towards energy conservation
  - corresponding behaviour
- Investment literacy: ability to perform an investment analysis and to calculate the lifetime cost of an appliance or energy-efficient renovation
- Attari et al. (2010), Brent and Ward (2017) and Blasch et al. (2016) → Positive role of investment literacy on adoption of efficient appliances
- Brounen et al. (2013)
  → Low level of energy literacy among households
  → No significant effect on energy consumption or on choice of thermostat setting

Contributions

- Efficiency estimation of an residential energy demand stochastic frontier model using a large sample of disaggregate panel data in a relatively new econometric approach (GTREM)
- One of the first paper that provides an analysis of the impact of energy and financial literacy on the total electricity consumption of households

Empirical specification (Log-log)

$$E_{it} = f(p_{it}^{E}, M_{it}, H_{it}, ES_{it}, LOC_{it}, W_{it}, LIT_{it}, BEH_{it}, T_t) + \varepsilon_{it}$$

E_{it} = electricity demand (in kWh) for household i in time period t

p_{it}^{E} = electricity price

M and H = vectors of household (incl. education) and dwelling characteristics

ES = level of energy services consumed

LOC = utility service area

W = HDD and CDD

LIT = level of energy and investment literacy of the respondent

BEH = energy saving behaviour of the household

$T_t and T_t^2$ = time trend t

ε_{it} = overall error term

Data – Survey

- 6 Swiss electric utilities $\sim$ 1994 households
- Survey organization
  - online surveys in 2015-2016
  - randomly chosen sample (also checked for representativeness)
  - consumption data: 2010-2014
- Questions include:
  - House/apartment characteristics
  - Socio-demographics
  - Appliance stock and energy services
  - Attitudes towards environment
  - Energy-related behaviour
  - Energy related knowledge (energy-literacy)
  - Investment literacy

Data – Variables of interest

- Energy literacy index (0 – 11)
  - average price of 1 kWh
  - usage cost of household appliances (2 Qs)
  - consumption of household appliances (3 Qs)
- Investment literacy dummy
  - compound interest calculation
- Energy-saving behaviour index (0 – 4)
  - washing machine only on full load
  - washing clothes at a lower temp
  - dishwasher cycle based on the level of dirtiness
  - switching off appliances after use

Estimation strategy – GTRE estimator

- Parametric stochastic frontier analysis $\rightarrow$ error term has two parts (separate inefficiency from noise)
- Generalized True Random Effects (GTRE) Model
  - Proposed by Colombi et al. (2014); Tsionas and Kumbhakar (2014); Kumbhakar et al. (2014); Filippini and Greene (2016)
  - Differentiate between between persistent and transient inefficiency
- Model: $y_{it} = \alpha + \boldsymbol{\beta}'\mathbf{x}_{it} + \varepsilon_{it}$
- Full random error: $\varepsilon_{it} = w_i + h_i + u_{it} + \nu_{it}$
  - $u_{it} \sim N^+[0, \sigma_u^2] \quad \rightarrow \mathrm{E}(u_{it}|y_i)$:transient inefficiency.
  - $h_i \sim N^+[0, \sigma_h^2] \quad \rightarrow \mathrm{E}(h_i|y_i)$: persistent inefficiency
  - $\nu_{it} \sim N[0, \sigma_\nu^2]$
  - $w_i \sim N[0, \sigma_w^2]$

Results

- Estimates of energy literacy score, investment literacy and behavioural index are negative and significant.
  - Households exhibiting energy-saving behaviour, electricity consumption is lower.
  - Households with higher level of energy and investment literacy are also associated with lower electricity consumption.
  - Though, investment literacy seems to play a more vital role.
- Estimation of an indicator of the level of energy efficiency for each household $\rightarrow$ Measure of efficiencies (median values)
  - Persistent efficiency: 78%
  - Transient efficiency: 89%

Conclusions

- Higher persistent inefficiency
  $\rightarrow$ Structural problems faced by households
  $\rightarrow$ Systematic behavioural shortcomings
- Positive role of energy related literacy and energy saving behaviour
- Further work
  - Total energy demand (gas+electricity)
  - Impact of policy measures
  - ...

Thank you for your attention...

QUESTIONS?
COMMENTS?

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BACKUP!

Results – Estimation

	Coefficient	*Std. error*
(Log) price of electricity	-0.3032***	(0.037)
(Log) energy saving behaviour	-0.0227***	(0.007)
(Log) energy literacy index	-0.0126***	(0.004)
Investment literacy	-0.1137***	(0.006)
Household and Dwelling characteristics	Yes	
Education level	Yes	
Energy services	Yes	
Service area dummies	Yes	
HDD and CDD	Yes	
Time trend (linear and quadratic)	Yes	
α	5.6722***	(0.719)
σ_w	0.3960***	(0.002)
$\sigma_{(\nu+u)}$	0.2542***	(0.003)
λ	0.7553***	(0.041)
σ_h	0.5411***	(0.017)
Observations:	8295	
Log-likelihood:	-1735.7	

***, **, * $\Rightarrow$ Significance at 1%, 5%, 10% level.

Results – Efficiency level

Efficiency type	*Median*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*
Transient	0.894	0.892	0.026	0.634	0.974
Persistent	0.785	0.784	0.013	0.394	0.841

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