The impact of energy prices on energy efficiency: Evidence from the UK refrigerator market

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The Energy Efficiency Gap

- A popular concept in policy circles
  - Potentially large differences between the socially and the actual level of energy consumption

- Two reasons
  - **The standard externality problem**: energy production and use generate health and environmental damages (in particular, fossil fuels)
  - **The potential existence of investment inefficiencies**: imperfect information and other cognitive constraints may lead consumers to discard privately profitable investments in energy efficiency

Investment Inefficiencies

- Any investment in energy efficiency entails
  - An upfront cost (a more expensive fridge)
  - A stream of future benefits (energy savings)
- Investment is inefficient if consumers use too high a discount rate
  - Consumers are « myopic »
- They buy too cheap refrigerators with a too low level of energy performance
- A rather old literature provides some evidence of very high discount rates
  - 39-300% for refrigerators: Revelt and Train, 1998; Hwang et al., 1994; McRae, 1985; Meier and Whittier, 1983; Gately, 1980; Cole and Fuller, 1980

Policy Implications

- Increasing energy prices is likely to trigger limited energy savings in the residential sector
  - Relative to energy efficiency standards or economic incentives targeting the investment decisions
- Two market failures = two instruments
  - A tax on energy use to internalize externalities
  - an instrument targeting the investment decisions (feebate for new cars, tax rebates for insulation, etc.)

The Impact of Energy Prices

The response to an increase in energy prices:

1. Consumers buy less refrigerators and, in relative terms, products that use less energy
   – A negative demand shock, stronger for less energy-efficient models
2. Manufacturers/retailers decrease refrigerators prices
   – Cuts are larger for less-energy efficient models.
   – Depends on the degree of competition in the market
3. Manufacturers/retailers change the characteristics of products supplied in the market
   – The launch of energy-efficient models, the withdrawal of less efficient ones

What We Do

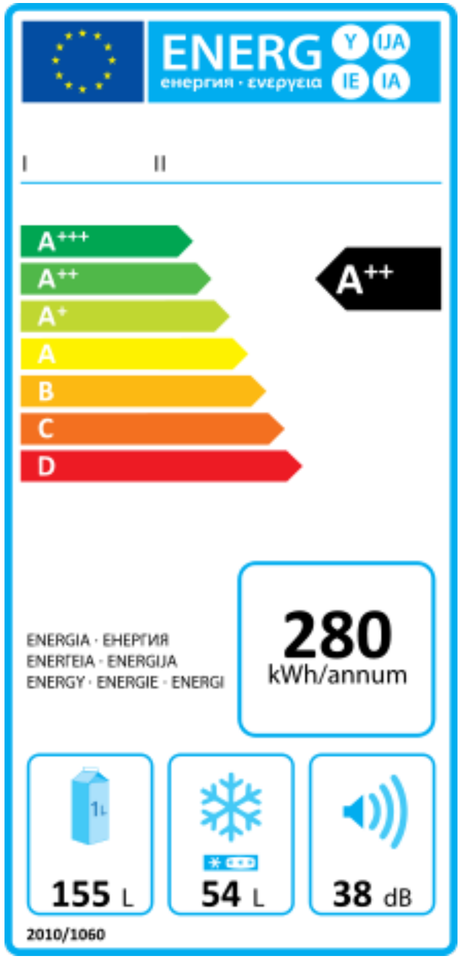
What is the impact of energy prices on residential energy use, taking into account both demand and supply responses?

1. How large are investment inefficiencies in energy use?
   - Which reduce the impact of energy prices on energy use
   - The level of the implicit discount rate
2. How large are refrigerator price adjustments?
   - Which reduce the impact of energy prices on energy use
3. How large are adjustments of product offers?
   - Which increase the impact of energy prices

- Using product-level panel data from 2002 to 2007 on the UK refrigerator market
  - Not available at the consumer level

Why Refrigerators?

- Energy efficiency matters
- The product is simple:
  - A few quality variables
- Energy consumption is completely determined at the time of purchase
    - Cannot adjust the level of consumption after purchase (no intensive margin)
    - In contrast with cars
- No markets for used fridges
    - In contrast with the car market
- Total demand is almost inelastic;;;
- EU Energy Label
  - Mandatory since 1995
  - « A+++ » cold appliances consume five times less energy than « D » appliances for the same cooling services.



Demand

- *T* markets, each representing the UK refrigerator market during year *t* with *J* (differentiated) products

- Indirect utility of consumer *i* who purchases a new refrigerator *j* in year *t*

$$U_{i,j,t} = V_{j,t} + \omega_{i,j,t} \qquad (1)$$

where $V_{j,t}$ is the average utility and $\omega_{i,j,t}$ is consumer *i*'s heterogeneity

- Under certain assumptions, Berry (1994) derives from (1):

$$\ln(s_{j,t}) - \ln(s_{0,t}) - \sigma \ln(s_{j/g,t}) = V_{j,t}$$

where $s_{0,t}$ and $s_{j/g,t}$ are respectively the market share of the outside good and of product *j* within its nest *g* at time t

Average utility

$$V_{j,t} = u_{j,t} - \alpha(p_{j,t} + \gamma C_{j,t})$$

with:

$u_{j,t}$, the value of usage of the refrigerator *j* over its lifetime

$p_{j,t}$, the purchase price

$C_{j,t}$ is the electricity cost of the product which is forecasted at the time of purchase

α is the marginal utility of money

γ is the parameter capturing the size of investment inefficiencies

A key objective of the paper is to test: $\boldsymbol{\gamma}$ = 1

The electricity cost

The (discounted) lifetime electricity cost of product *j* is

$$C_{j,t} = \Gamma_j \times \sum_{s=1}^{L_j} q_{t+s}^* / (1+r)^s$$

Where:

- Γ_j is the level of energy consumption per time period
- L_j is product *j*'s lifetime
- is the discount rate
- q_{t+s}^* is the forecasted electricity price at time $t+s$

Econometric issues

- q_{t+s}^{*} is not the actual price, but the price that is anticipated at the date of purchase.
  - **Solution** : Predicted with an autoregressive integrated moving-average model (ARIMA) on monthly data on real electricity prices
- $u_{j,t}$ is not observed.
  - **Solution**: We assume $u_{j,t} = u_j + \xi_{j,t}$, which can be partly controlled using first differences
- $p_{j,t}$ is endogenous because quantities and prices are simultaneously determined in the market equilibrium
  - **Solution** : IV-GMM estimation; instruments: out-of-group and within-group average capacity and out-of-group price

- **The estimated specification is**

$$\Delta \ln(s_{j,t}) = -\alpha(\Delta p_{j,t} + \gamma \Delta C_{j,t}) + \Delta \tau_t + \Delta \xi_{j,t}$$

Where Δ= difference operator, $\Delta \tau_t$ are time dummies differences absorbing the outside good market share and other time varying factors

Refrigerator price

- A reduced-form equation:

$$p_{j,t} = p^{0}_{j,t} - \eta C_{j,t} + \epsilon_{j,t}$$

where $p^{0}_{j,t}$ is the price of product *j* at time *t* if electricity cost during its lifetime is zero and $\epsilon_{j,t}$ is an error term.

- We do not observe $p^{0}_{j,t}$. We assume that:

$$p^{0}_{j,t} = p^{0}_{j} + \nu_{t}$$

- **We estimate:**

$$\Delta \boldsymbol{p}_{\boldsymbol{j},\boldsymbol{t}} = \Delta \boldsymbol{\nu}_{\boldsymbol{t}} - \boldsymbol{\eta} \Delta \boldsymbol{C}_{\boldsymbol{j},\boldsymbol{t}} + \boldsymbol{\mu} \boldsymbol{X}_{\boldsymbol{j},\boldsymbol{t}} + \Delta \boldsymbol{\epsilon}_{\boldsymbol{j},\boldsymbol{t}}$$

where $X_{j,t}$ is the vector of instruments

Product offer

- We observe the products in the market
- A dynamic probit model:

$$d_{j,t} = \Phi(k_d\, d_{j,t-1}^{*} + k_p\, p_{j,t} + k_c\, C_{j,t} + \lambda_t + \omega_j)$$

Where

- $d_{j,t}$ is the probability product j is in the market at time t
- $d_{j,t-1}^{*}$ is a binary variable indicating whether the product was in the market at time t-1
- $p_{j,t}$ and $C_{j,t}$ are the product price and electricity cost
- λ_t and ω_j are time dummies and fixed effects

Problem: $p_{j,t}$ is not observed when the product is not in the market

Solution: multiple imputations (Wooldridge, 2005)

Data

GfK sales data for the UK market – 2002-2007

Variable	Unit	Mean	Std dev
Annual sales	# of units	2226	5054
Purchase price, $p_{j,t}$	real £	402	289
Appliance lifetime, L_j	years	15.38	2.34
Energy consumption, Γ_j	kWh/year	320	145
Height	cm	142	43
Width	cm	60	10
Capacity	litres	252	115
Energy efficiency rating[a]		2.46	0.88
Share combined refrigerators-freezers		0.55	-
Share of built-in appliances		0.22	-
Share of appliances with no-frost system		0.24	-
Instrumental variables			
Within-group: capacity	litres	254	111
Out-of-group: capacity	litres	268	22

Results (1): Sales

Dependent variable	Eq. (6): Log market share of product *j*
Importance of total electricity costs (γ)	0.6007*** (3.32)
Utility for money (α)	0.0056*** (2.82)
Within-group correlation of error term (σ) for the demand equation	0.6522*** (5.59)
Year dummies	Yes
Observations	1,623
Test of over-identifying restriction	Hansen's J chi2(2) = 1.80 (p = 0.4060)

Investment inefficiencies are limited = $\boldsymbol{\gamma \cong 0.6 \Leftrightarrow \textit{implied discount rate is } 10\%}$

Much lower than previous studies. Two possible explanations:

- Energy labeling
- Methodology (panel data)

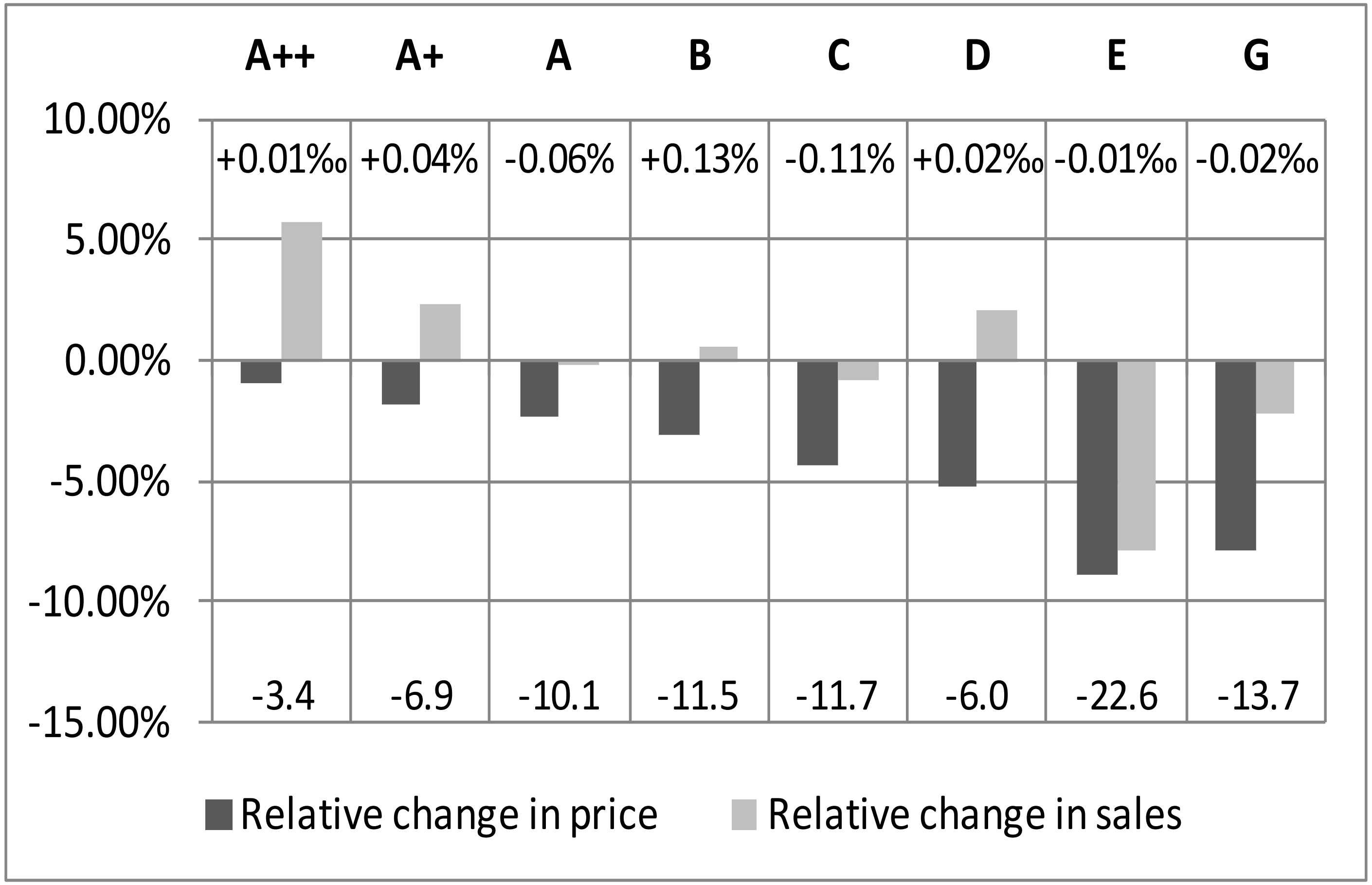
Results (2): Price

Dependent variables	Eq. (7): Price of product *j*
Impact of discounted electricity costs on appliance prices (η)	-0.2860*** (2.83)
Out-of-nest price	-3.11*** (-3.7)
Out-of nest capacity	11.27*** (4.5)
Within nest capacity	1.19 (1.35)
Year dummies	Yes
Observations	1,623

Manufacturers/retailers reduces prices in response to an increase in electricty cost

The price response is asymmetric

- The impact of a 10% increase of the electricity cost is higher on less energy efficient models:



Manufacturers/retailers partly compensate the electricity price increase

Results (3): Product offer

Dependent variables	Eq. (10): Availability of product *j*
The product was commercialised the year before (k_d)	0.9124*** (37.16)
Appliance price (k_p)	-0.0011*** (3.89)
Expected and discounted running costs (k_c)	-0.0024*** (3.44)
The product was commercialised in 2002 (k_1)	-0.5715*** (17.70)
Nonredundant explanatory variables covering all time periods and including time-constant product features (k_z)	Yes
Year dummies	Yes
Observations	12,160
Number of imputations for appliance prices	10

1. **Electricity cost has a significant impact**

Impact on energy use

	Electricity price 10% higher		
Relative change in average energy consumption (kWh/year) as compared to the baseline	Short term impact on market shares	With purchase price adjustments	With purchase price adjustments and change in product offer
Consumers are myopic and competition is imperfect	-2.2%	-1.2%	-2.3%

- The long term elasticity is rather low : -0.23
- Without investment and market inefficiencies, it would be -0.6

Size of the two inefficiencies

Relative change in average energy consumption (kWh/year) as compared to the baseline	
Consumers are myopic and competition is imperfect	-2.3%
Consumers are perfectly rational but competition is imperfect	-3.9%
There is perfect competition but consumers are myopic	-3.6%
Consumers are perfectly rational and there is perfect competition	-6.0%

- In the long run, investment inefficiencies and imperfect competition have the same (negative) impact on energy efficiency

Policy implications (1)

- Energy taxation may not be very effective
- Solutions?

1. Energy labeling
   - Done since 1996. Only addresses the behavioral inefficiency.
2. Energy standards
   - A constraint on the set of products available in the market
3. Subsidization of investments in energy efficiency or feebates (bonus/malus)
   - Decrease the purchase price of good products

- The welfare analysis is extremely complex
  - Cannot only focus on the demand response and consumer surplus
  - Much more than the analysis carried out in several recent papers
    - E.g., Allcott and Wozny, 2014

Policy implications (2)

- A welfare analysis is not feasible
  - Stuctural approach limited to demand
- A partial analysis focusing on demand and consumer surplus is
  - Done in several recent papers (e.g., Allcott and Wozny, 2014)
  - But our analysis that this approach is not appropriate for supply responses are important

Conclusions

- The long term impact of energy prices on energy use is rather low
  - Elasticity is – 0.23
- We find evidence of investment inefficiencies, but limited. The implied discount rate is 10%
  - Mandatory energy labeling?
- The impact on energy use of the asymmetric price response which partly absorbs the increase in energy price has the same order of magnitude
- Innovation – changes in product offer – partly compensates these two effects
- If competition on the refrigerator market was perfect and consumers were rational, the elasticity would be – 0.60
- Policy implications?
  - Direct regulation
  - Investment subsidies are likely to be ineffective

Thank you !