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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 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.)

Supply responses on the fridge market

An increase in energy prices which lowers the demand for refrigerators, in particular less energy-efficient models, also potentially induces:

1. cuts in refrigerator prices
   - Cuts are larger for less-energy efficient models.
   - Depends on the degree of competition in the market
2. changes in the product portfolio supplied in the market
   - The launch of energy-efficient models, the withdrawal of less efficient ones

This paper

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

Demand

- *T* markets, each representing the UK refrigerator market during year *t* with *J* (differentiated) products
- Bertrand competition
- Indirect utility of consumer *i* who purchases a new refrigerator *j* in year *t*

$$U_{i,j,t} = V_{j,t} + \omega_{i,j,t}$$

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

- Under certain assumptions, in particular:
  - A consumer can also choose an outside option indexed 0 which consists in purchasing no refrigerator
  - Consumers' idiosyncratic preferences are correlated across refrigerators within the same product group (nest), and zero otherwise
- Berry (1994) derives:

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

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

This equation can be estimated with market-level data

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: γ = 1

The electricity cost

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

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

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 $\mathrm{u_{j,t} = u_j + \xi_{j,t}}$, 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**

$$\Delta \mathbf{ln}\left(\boldsymbol{s}_{\boldsymbol{j},\boldsymbol{t}}\right) = -\boldsymbol{\alpha}\left(\Delta \boldsymbol{p}_{\boldsymbol{j},\boldsymbol{t}} + \boldsymbol{\gamma}\Delta \boldsymbol{C}_{\boldsymbol{j},\boldsymbol{t}}\right) + \Delta \boldsymbol{\tau}_{\boldsymbol{t}} + \Delta \boldsymbol{\xi}_{\boldsymbol{j},\boldsymbol{t}}$$

where $\Delta\tau_t$ are time dummies 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:**

$$\boldsymbol{\Delta p_{j,t} = \Delta \nu_t - \eta \Delta C_{j,t} + \mu X_{j,t} + \Delta \epsilon_{j,t}}$$

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

Product offer

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

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

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
[illegible]	[illegible]	[illegible]	[illegible]

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 = $\boldsymbol{\gamma \cong 0.6 \Leftrightarrow implied\ discount\ rate\ is\ 10\%}$

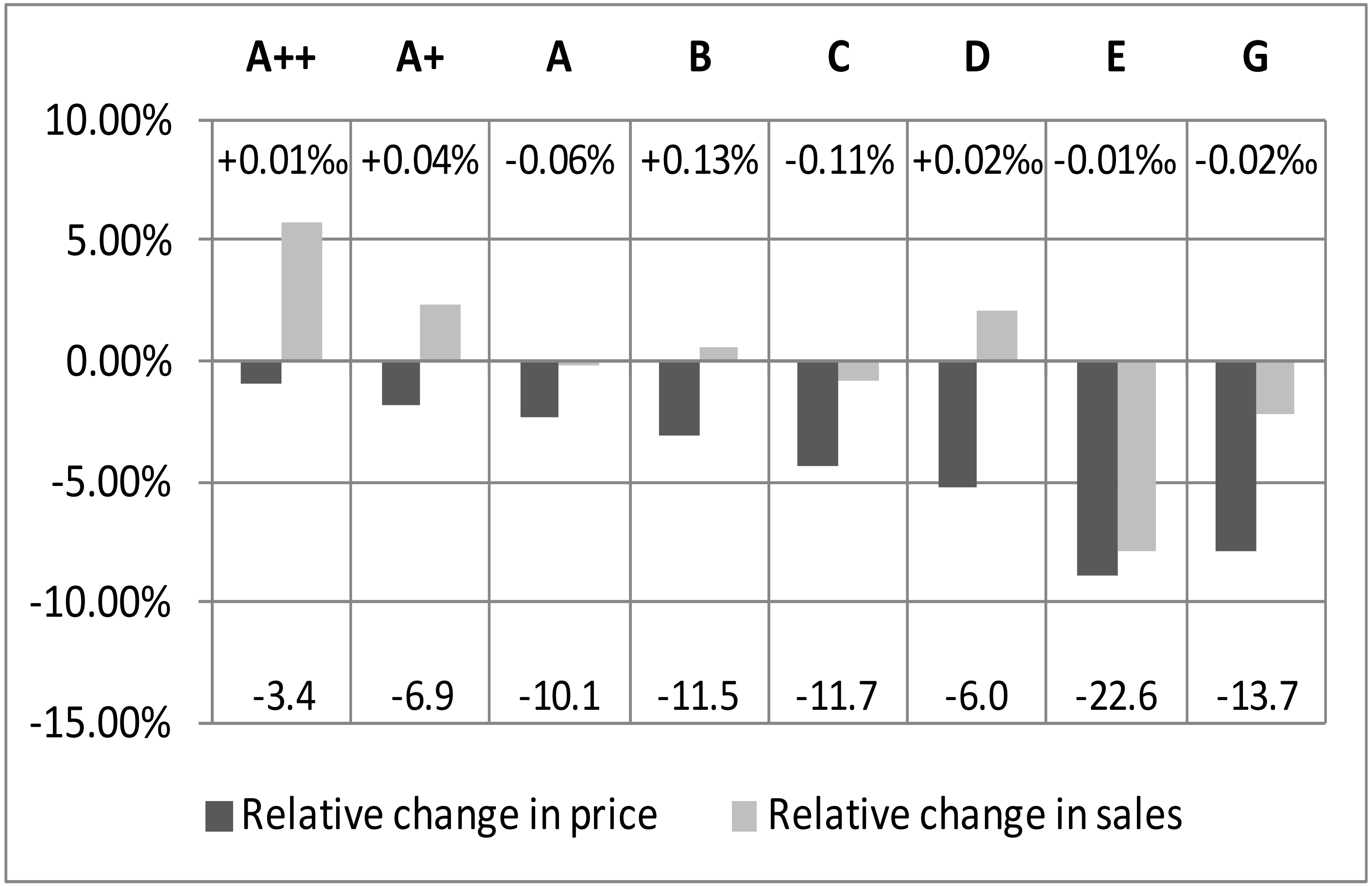
Results (2): Price

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
- The impact of the two inefficiencies is similar

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 !

Why the refrigerator market?

- 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
    - In contrast with cars
  - No markets for used fridges
    - In contrast with the car market

- EU Energy Label since 1995
  - « A+++ » cold appliances consume five times less energy than « D » appliances for the same cooling services.