Green Cars Adoption and the Supply of Alternative Fuels

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Motivation

- Public interest in fostering adoption of alternative fuel (AF) cars.

  23 April 2009: European Directive sets a market share target for Green cars.

  17 September 2014: European Directive on the deployment of alternative fuels infrastructure

- Complementarity fuel - cars.

- Not clear theoretical predictions.

- Role of availability of fuels mainly studied through household surveys.

- Italy interesting case study:
  - Share of AF cars is increasing
  - Growing supply of alternative fuels
  - Significant legislative activity
  - Variation between local markets.

Methodological Approach and Research Question

- How important is fuel availability for adoption of green cars?
- Can adoption be incentivized acting on the retail fuel industry?
- Estimate model:

  $\Rightarrow$ Demand of cars (fuel cost and availability = car characteristics)

  $\Rightarrow$ Model of entry (filling stations supply of alternative fuels)
- Compare two policies:

  $\Rightarrow$ Price rebates for green cars.

  $\Rightarrow$ Filling station subsidies to installe alternative fuel pumps.

Related Literature

Adoption of fuel-efficient cars

Klier and Linn(2008,2011),
Huse and Lucinda (2013), Langer and McRae (2013),
Shiver(2015), Li et al. (forthcoming).

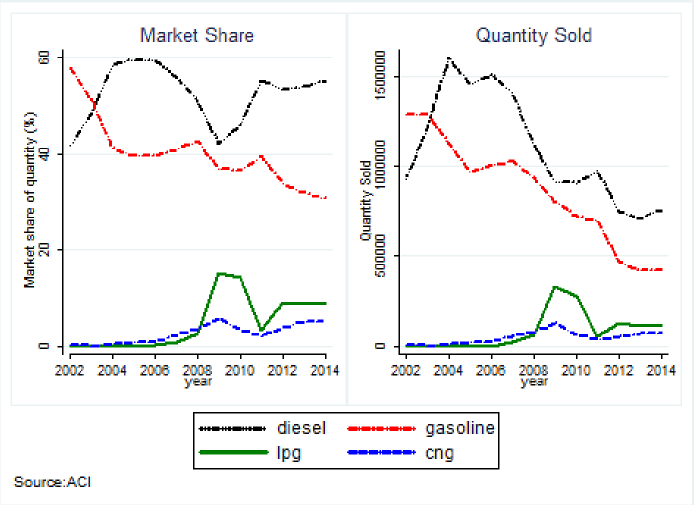
Demand of a durable good and supply of complementary goods

→ Berry(1994), Berry, Levinsohn and Pakes (1995) and Verboven (1996).
→ Network externalities: Katz and Shapiro (1986).

Models of Entry

Breshnan and Reiss(1991), Berry and Waldfogel (1999).

Vehicles by type of fuel. Italy 2002-2014



Definition of market.

- Labour Market Areas
  - Sub-regional geographical areas.
  - Based on the analysis of commuting patterns.
  - 611 distinct areas.
  - Source: Italian National Institute of Statistics (Istat)

Data: vehicles.

- Cars sales from ACI (Automobile Club d'Italia).
  - Flow Car sales in 2012 at municipality level.
    Disaggregated by model, body style, engine displacement and fuel.
  - Stock Registered cars in 2011 by municipality and fuel.
- Car characteristics collected from *Quattroruote* and *Panoramauto*.
  Characteristics: price, type of fuel, physical attributes and performance measures.

Data: filling stations.

- Filling station location from www.prezzibenzina.it. Geographic coordinates, entrance year, fuels supplied and brand.
- Margin from experts of the sector.
- Fuel consumption from MISE LPG consuption at province level.
- Land value from the Revenue Agency.

Model: Overview

- Two agents: Consumers and Filling Stations.
- Timing:
  - Stock of cars previous years is given.
  - Filling stations enter all at the beginning of the year (2012) and decide whether to install an AF pump.
  - Consumers choose which car to buy given the density of filling stations.

Demand: nested logit model

- Assume $m = 1, \ldots, M$ markets, $h = 1, \ldots, H_m$, households, $j(f) = 1, \ldots, J(f)$ car models installing an engine compatible with fuel $f = 1, \ldots, F$.
- Nests: fuels.
- Indirect utility:

$$u_{hj(f)m} = \delta_{j(f)m} + \nu_{hj(f)m}$$

$$\delta_{j(f)m} = \alpha p_{j(f)} + x_{j(f)}\beta + n_{fm}\lambda_h + \xi_{j(f)m}$$
$$\nu_{hj(f)m} = \zeta_{hfm} + (1-\sigma)\varepsilon_{hj(f)m}$$

x_j car characteristics (power/weight, acceleration, length and fuel costs).
n_{fm} number of filling station per km^2 (depends on fuel).

Demand: Estimation and Identification

- Estimating equation:

$$ln\left(\frac{s_{j(f)m}}{s_{0m}}\right) = \alpha p_{j(f)m} + x_{j(f)}\beta + n_{j(f)m}\lambda + \sigma \ln s_{j(f)|fm} + \xi_{j(f)}$$

$s_{j(f)|fm}$ market share of the product $j(f)$ within the fuel f.

- I am exploiting the cross sectional differences in: sales taxes; fuel price; density of filling stations.
- Instruments for price and within group share:
  - sum of characteristics (same group/other group);
  - demand shifters per fuel due to local legislation.

Entry model: assumptions

- Traditional fuel filling station decide whether to add an alternative fuel pump
- Functional form for profit:

$$\Pi_{im} = \underbrace{(p_{im} - c_i) l_i(p_{im}, p_{-im}, n_m)}_{VP_i(n_m)} - F_{im}$$

- $(p_{im} - c_i)$ price margin
- $l_i(p_{im}, p_{-im}, n_m)$ total liters of fuel sold.
- Fixed cost: $ln(F_i) = \gamma W_m + \omega \nu_m$
  W_m cost shifters; $\nu_i \sim \mathcal{N}$; γ and ω: parameters to estimate.
- Firms offering fuel f are symmetric. c_i set at national level. Drivers split their fuel consumption equally across gas station
  $\Rightarrow p_{f,i} = p_{f,\text{-}i}$, $VP_{f,i} = VP_{f,\text{-}i}$, $F_{f,i} = F_{f,\text{-}i}$.

Entry model: Implementation

1. Compute VP:
   - $(p_i - c)$ecomotori.net and "*Staffetta Quotidiana*".
   - $l_i(q(n)) = \frac{1}{n}[k(q(n) + Q)]$
     - n number of filling stations in the market (prezzibenzina.it).
     - k mean alternative fuel consumed per car in the market (MISE).
     - $q(n)$ Estimated from the demand model.
     - Q stock of cars in the market (ACI).

2. Firm install a pump of fuel f as long as it is profitable.

3. Observing n entrants in a market if and only if:
4. VP_i and F_i equal within each market $\rightarrow$ conditions above hold at mkt level.

5. Zero profit condition bounds:

$$\frac{ln(E_{\xi|\theta}(vp_m(n_m + 1; \xi, \theta)) - \gamma W_m}{\omega} \leq \nu_m \leq \frac{ln(E_{\xi|\theta}(vp_m(n_m; \xi, \theta)) - \gamma W_m}{\omega}$$

6. Estimate by maximum likelihood.

Table : Demand Results

VARIABLES	(1) Logit Demand	(2) IV Logit Demand	(3) IV Nested Logit
price	-0.03	-0.11	-0.14
	(0.0012)	(0.0119)	(0.0071)
sigma			0.27
			(0.011)
log(power/weight)	-10.89	5.76	10.09
	(0.515)	(2.320)	(1.369)
log(euro/100km)	0.08	0.06	0.04
	(0.006)	(0.007)	(0.005)
log(acceleration)	-0.71	0.09	0.33
	(0.039)	(0.115)	(0.069)
log(length)	-0.03	0.02	0.03
	(0.003)	(0.008)	(0.005)
lpg*pump/kmsq	0.16	0.16	0.19
	(0.007)	(0.007)	(0.005)
cng*pump/kmsq	0.54	0.54	0.60
	(0.021)	(0.021)	(0.016)
diesel*pump/kmsq	-0.00	-0.00	-0.00
	(0.000)	(0.001)	(0.000)
gasoline*pump/kmsq	0.01	0.01	0.01
	(0.001)	(0.001)	(0.001)
R^2	0.60	0.58	0.76
mean elasticity	0.56	-2.46	-3.31

Fuel FE, Market FE, Segment FE, included in all specifications
Standard errors in parentheses.

Table : Demand Results (cont'd)

VARIABLES	IV Nested Logit
price	-0.14
	(0.011)
sigma	0.27
	(0.011)
lpg*pump/kmsq	0.19
	(0.05)
cng*pump/kmsq	0.60
	(0.016)
diesel*pump/kmsq	-0.00
	(0.000)
gasoline*pump/kmsq	0.01
	(0.001)
R^2	0.76
mean elasticity	-3.31

Table : Substitution Patterns

	average	average cross elasticity wrt car with fuel:			
fuel group	own elasticity	lpg	cng	diesel	gasoline
lpg	-2.505	0.057	0.002	0.002	0.001
cng	-2.955	0.001	0.096	0.002	0.001
diesel	-3.881	0.002	0.002	0.014	0.001
gasoline	-2.535	0.002	0.002	0.002	0.017

Table : Entry Results

VARIABLES	LPG	CNG
constant	10.06	11.25
	(0.24)	(0.29)
ln(land value)	0.07	-0.01
	(0.02)	(0.02)
mandatoryAF	0.12	-0.13
	(0.08)	(0.12)
north-east	-0.02	0.31
	(0.12)	(0.14)
center	0.00	0.68
	(0.11)	(0.14)
south	-0.13	0.30
	(0.11)	(0.14)
islands	-0.32	-0.38
	(0.12)	(0.21)
ω	0.74	0.76
	(0.02)	(0.03)
Observations	611	572
Implied fixed costs	23456	77095

Car price rebate vs. filling station subsidies

- Compare price incentives and entry incentives.
  - price reduction of alternative fuel cars $\rightarrow \Delta$ market share.
  - reduction of the fixed costs (γ_0) $\rightarrow \Delta$ number of filling stations that would satisfy entry condition.
- Choose realistic policies and similar government expenditure.

LPG:

- Price rebate: 2.2 €
- Fixed cost subsidies: 60%
- Gov. exp.: $\sim$ 175 mln

CNG:

- Price rebate: 2.5 €
- Fixed cost subsidies: 40%
- Gov. exp.: $\sim$ 100 mln

- Distinguish "direct" and "overall" effects.
  - "direct" effect of the policy:

    $\Delta p \rightarrow \hat{s}_f$, keeping fixed all other variables.
    $\Delta \gamma_0 \rightarrow \hat{n}_f$, keeping fixed all other variables.
  - "overall" effect of the policy:

    $\Delta p \rightarrow$ compute $\hat{s}_f$ $\hat{n}_f$ implied by demand and entry model.
    $\Delta \gamma_0 \rightarrow$ compute $\hat{s}_f$ $\hat{n}_f$ implied by demand and entry model.

LPG

Table : Price Rebate

	Avg (% Δ)	5^{th} LPG percentile (%Δ)	95^{th} LPG percentile (% Δ)
		Direct effect	
Subsidized fuel	**22.15**	**27.88**	**27.21**
Other fuels	-0.48	-0.11	-0.64
		Overall effect	
Subsidized fuel	**27.78**	**25.07**	**30.90**
Other fuels	-0.55	-0.91	-1.17
pump density	1.10	0.00	11.81

Table : Filling station subsidy

	Avg (% Δ)	5^{th} density percentile (%Δ)	95^{th} density percentile (% Δ)
		Direct effect	
pump density	68.28	0.00	160.85
		Overall effect	
Subsidized fuel	**40.77**	**2.62**	**10.63**
Other fuels	-2.18	0.06	-0.10
pump density	81.98	0.00	221.54

CNG

Table : Price Rebate

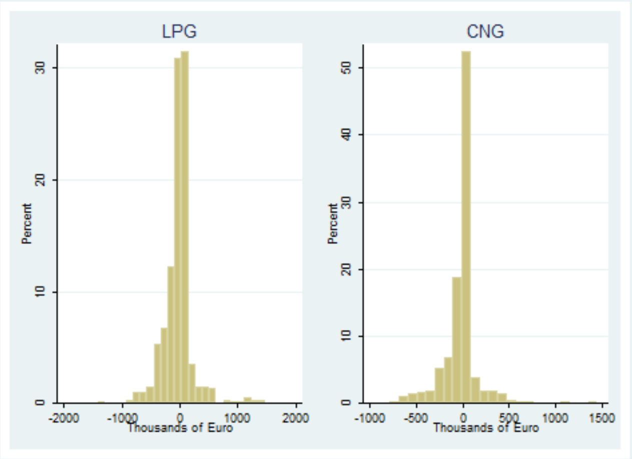
	Avg (% Δ)	5^{th} CNG percentile (%Δ)	95^{th} CNG percentile (% Δ)
		Direct effect	
Subsidized fuel	**15.73**	**0.00**	**31.91**
Other fuels	-1.09	0.00	-0.38
		Overall effect	
Subsidized fuel	**27.61**	**0.00**	**58.48**
Other fuels	-0.82	0.00	-2.25
pump density	3.99	0.00	52.63

Table : Filling station subsidy

	Avg (% Δ)	5^{th} density percentile (%Δ)	95^{th} density percentile (% Δ)
		Direct effect	
pump density	24.81	0.00	142.77
		Overall effect	
Subsidized fuel	**65.49**	**0.00**	**136.85**
Other fuels	-4.63	0.00	-0.68
pump density	55.12	0.00	145.66

Policy comparison: Market level

- Price rebate - filling station subsidy



Policy comparison: CO_2

- Total number of vehicles sold increase (total CO_2).
- CO_2 per car emissions decrease (car manufacturer's measures).
- No data on other pollutants.

	LPG (g/km)	CNG (g/km)
	Average CO2 per car	
Price Subsidy	-0.01	-0.33
Filling Station Subsidy	-0.15	-0.97

Setting filling station standards.

- Lower bound: set AF pump density = average 2012 AF pump density.
- Upper bound: set AF pump density = 2012 gasoline pump density.

	Average AF pump density Avg Δ market share (%)	Gasoline pump density Avg Δ market share(%)
LPG	5.12	118.42
CNG	1.55	3317.80
Diesel	-0.07	-22.73
Gasoline	-0.07	-22.73

Conclusions

- Model the co-determination of AF vehicle demand and AF supply.
- Evidences of the crucial effect of the higher density of AF filling station on the choice of car adoption.
- Compare two policies acting on the two sides of the market.
  - Price rebate:
    - effective in fostering the use of AF cars (28%);
    - weak effect on AF pump density (1 - 4%);
    - AF cars temporarily more appealing.
  - Filling station subsidy:
    - effective in fostering the use of AF cars (40 - 66%);
    - effective in increasing filling station density (50 - 80%);
    - a permanent improvement in the ease to refill green cars.
- Environmental effects(?)

Thank you.