

# 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:
  - ⇒ Demand of cars (fuel cost and availability = car characteristics)
  - ⇒ Model of entry (filling stations supply of alternative fuels)
- Compare two policies:
  - ⇒ Price rebates for green cars.
  - ⇒ Filling station subsidies to install 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), Springel (2016), Li et al. (2016).

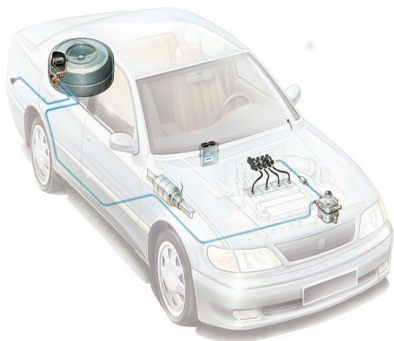
## Demand of a durable good and supply of complementary goods

→ 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).

## LPG vehicle



By-product of petroleum refining  
or natural gas processing

(98% to 99% if from NG production).

## CNG vehicle



Underground reserves  
and renewable biogas

(83% if running on RNG).  
Produce no evaporative emissions.

# Vehicles by type of fuel. Italy 2002-2014



▶ (Filling station)

▶ (Producers)

▶ (Segments)

# Data

- **Definition of market:** Labour Market Area ▶ (Market characteristics.)
- **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*.  
Price, type of fuel, physical attributes and performance measures.
- **Prices of fuels** from ecomotori.net and ISTAT  
Price at province level. ▶
- **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 consumption at province level.
- **Land value** from the Revenue Agency. ▶

## Demand: nested logit model

- Indirect utility of household  $h$  buying product  $j(f)$  in market  $m$ :

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

$$\delta_{j(f)m} = \alpha p_{j(f)} + x_{j(f)}\beta + n_{fm}\lambda_h + \xi_{j(f)m}$$

$$\nu_{j(f)m}^h = \varepsilon_{fm}^h + (1 - \sigma_2)\varepsilon_{sfm}^h + (1 - \sigma_1)\varepsilon_{jm}^h$$

$x_j$  car characteristics.

$n_{fm}$  logarithm of the number of filling station per  $km^2$ .

- Nests: fuels, segment.
- Estimating equation:

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

$$+ \sigma_1 \ln s_{j(f)|sfm} + \sigma_2 \ln(s_{s|fm}) + \xi_{j(f)}$$



# Entry model: Assumptions

- Traditional fuel filling station decide whether to add an AF pump
- 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;  $\nu_i \sim \mathcal{N}$ ;  $\gamma$  and  $\omega$ : parameters to estimate.
- Firms offering fuel  $f$  are symmetric. Drivers split equally across gas station.  $\Rightarrow p_{f,i} = p_{f,-i}$ ,  $VP_{f,i} = VP_{f,-i}$ ,  $F_{f,i} = F_{f,-i}$ .
- Zero profit condition bounds:  

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

Table: Demand Results

	IV 2Nested Logit	IV 2NL instrument density
	(1)	(2)
Price (thousands of €)	-0.018*** (0.0029)	-0.012*** (0.0028)
$\log(N/M) * AF$	0.37*** (0.006)	0.65*** (0.02)
$\log(N/M)$	0.034*** (0.002)	-0.014*** (0.005)
Power/weight (kw/kg)	2.49*** (0.47)	1.53*** (0.45)
fuel cost (€/100 km)	-0.005* (0.002)	-0.007*** (0.002)
length (cm)	0.002*** (0.0003)	0.002*** (0.0003)
$\sigma_1$	0.92*** (0.003)	0.91*** (0.003)
$\sigma_2$	0.83*** (0.007)	0.83*** (0.007)
implied price elasticity	-4.42	-2.8
N	141000	141000

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table: Entry Results

VARIABLES	LPG	CNG
constant	7.39 (0.40)	7.20 (0.56)
ln(pop)	0.33 (0.03)	0.35 (0.05)
mandatoryAF	0.13 (0.06)	0.04 (0.09)
north-east	-0.16 (0.09)	0.48 (0.11)
center	-0.07 (0.09)	0.84 (0.11)
south	-0.14 (0.09)	0.29 (0.11)
islands	-0.25 (0.09)	-0.27 (0.16)
cost shifter	-0.03 (0.04)	0.05 (0.07)
$\omega$	0.60 (0.02)	0.63 (0.03)
Observations	572	543

## 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 ( $\gamma_0$ )  $\rightarrow \Delta$  number of filling stations that would satisfy entry condition.
- Choose realistic policies and similar government expenditure.

### LPG:

- Price rebate: 1.700 €
- Fixed cost subsidies: 60%
- Gov. exp.:  $\sim$  270 mln

### CNG:

- Price rebate: 1.7 €
- Fixed cost subsidies: 60%
- Gov. exp.:  $\sim$  300 mln

## LPG policy comparison

	Price Rebate			Filling station subsidy		
	Avg	5 <sup>th</sup>	95 <sup>th</sup>	Avg	5 <sup>th</sup>	95 <sup>th</sup>
	(% Δ)	percentile (%Δ)	percentile (% Δ)	(% Δ)	percentile (%Δ)	percentile (% Δ)
<i>Direct effect</i>						
<i>Car purchases</i>						
<b>Subsidized</b>	<b>2.28</b>	<b>0.00</b>	<b>0.00</b>			
Others	-0.05	0.00	0.00			
<i>Pump density</i>						
				89.56	0.00	173.66
<i>Overall effect</i>						
<i>Car purchases</i>						
<b>Subsidized</b>	<b>2.26</b>	<b>0.00</b>	<b>6.17</b>	<b>47.67</b>	<b>34.99</b>	<b>48.47</b>
Others	-0.05	0.00	0.00	-1.22	-0.25	-1.70
<i>Pump density</i>						
	0.12	0.00	0.00	111.23	0.00	251.97

## CNG policy comparison

	Price Rebate			Filling station subsidy		
	Avg (% $\Delta$ )	5 <sup>th</sup> percentile (% $\Delta$ )	95 <sup>th</sup> percentile (% $\Delta$ )	Avg (% $\Delta$ )	5 <sup>th</sup> percentile (% $\Delta$ )	95 <sup>th</sup> percentile (% $\Delta$ )
<i>Direct effect</i>						
<i>Car purchases</i>						
<b>Subsidized</b>	<b>1.92</b>	<b>0.00</b>	<b>1.82</b>			
Others	-0.03	0.00	-0.07			
<i>Pump density</i>						
				59.69	0.00	188.76
<i>Overall effect</i>						
<i>Car purchases</i>						
<b>Subsidized</b>	<b>2.15</b>	<b>0.00</b>	<b>6.31</b>	<b>34.32</b>	<b>0.00</b>	<b>66.92</b>
Others	-0.03	0.00	-0.08	-0.55	-0.00	-0.78
<i>Pump density</i>						
	0.80	-2.51	14.81	80.74	0.00	288.12

# Conclusions

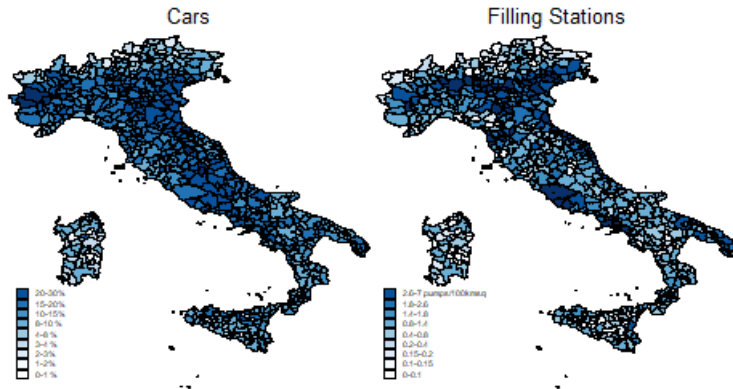
- Model the co-determination of AF vehicle demand and AF supply.
- Evidences of the crucial effect of the higher density of AF filling station on the choice of car adoption.
- Compare two policies acting on the two sides of the market.
  - Price rebate:
    - effective in fostering the use of AF cars ( $\sim 3\%$ );
    - weak effect on AF pump density ( $0.5\%$ );
    - AF cars temporarily more appealing.
  - Filling station subsidy:
    - effective in fostering the use of AF cars ( $35 - 50 \sim\%$ );
    - effective in increasing filling station density ( $80 - 100 \sim \%$ );
    - a permanent improvement in the ease to refill green cars.
- Environmental effects(?)

Thank you.



# Share of new cars 2012 and pumps location - LPG

Lpg

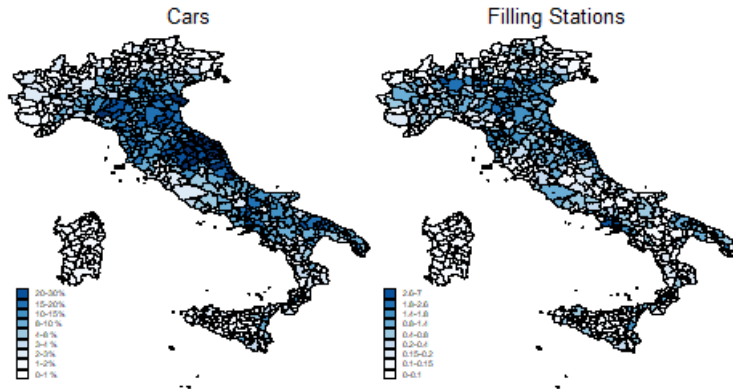


Source: ACI and prezzibenzina.it

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# Share of new cars 2012 and pumps location - CNG

Cng



Source: ACI and prezzibenzina.it

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## Market characteristics

	Mean	St. Dev.	5th pctile	25th pctile	50th pctile	75th pctile	95th pctile
Surface	494	403	102	243	390	624	1283
Population	97,272	258,292	6,988	21,890	45,032	87,339	280,661
cars sold LPG	174	574	3	13	48	145	588
cars sold CNG	91	177	1	5	25	90	382
cars sold DIESEL	638	1611	35	109	273	622	2145
cars sold GASOL.	496	1745	15	52	150	408	1588
stations LPG	5.03	8.72	0	1	2	6	18
stations CNG	1.54	2.96	0	0	0	2	6
stations traditional fuels	33.40	70.74	3	8	18	34	91

Sources: Prezzibenzina.it, ISTAT and ACI.

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Table: Number of filling stations over years

year	lpg	cng
2000	1949	336
2002	2126	402
2006	2311	529
2008	2351	665
2009	.	693
2010	2364	718
2011	2350	718
2012	3201	896
2013	3275	974

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**Table:** Summary statistics - Market share by manufacturer and fuel type.

<b>Car builder group</b>	<b>Gasoline</b>	<b>Diesel</b>	<b>LPG</b>	<b>Natural gas</b>
Fiat	9.0 %	7.1%	5.5%	4.7%
Volkswagen	3.8%	8.4%	0.3%	0.2%
BMW	1.19%	2.5%		
GM(Chevrolet, Opel)	3.2%	3.4%	2.7%	0.4%
PSA (Citroen Peugeot)	4.2%	5.1%	0.7 %	
Renault	2.5 %	5.9%	2.1%	
Daihatsu Motor Co., Ltd (Toyota)	3.9%	1.6%		
Ford	2.5%	4.6%	1.1%	
Hyundai	2.9%	3.7%	0.2%	
Mercedes	0.4%	1.5 %		0%
Suzuki	1.2%	0.3%	0%	

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Table: Numver of variants by segment.

VARIABLES	LPG	CNG	DIESEL	GASOLINE
Subcompact	8	2	25	68
Compact	39	5	73	130
Intermediate	21	6	185	206
Standard	9	4	150	113
SUV	12	3	103	62
Sport	1	0	10	48
Luxury	0	1	101	45

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- Log-likelihood.

$$\mathcal{L}(\theta) = \sum \ln (\Phi (\ln(vp_m(n_m)) - \gamma W_m) - \Phi (\ln(VP_m(n+1)) - \gamma W_m))$$

- Substitute  $vp_m(n_m)$  with its fitted value.

$$\mathcal{L}(\theta) = \sum_m \ln \left( \Phi \left( \ln((p_m - mc_i)k \frac{1}{n_m} \left( \sum_{j \in \mathcal{C}_f} \hat{\sigma}_j(n_m) \right) (1 + \phi_m))) - \gamma W_m \right) \right. \\ \left. - \Phi \left( \ln((p_m - mc_i)k \frac{1}{n_m + 1} \left( \sum_{j \in \mathcal{C}_f} \hat{\sigma}_j(n_m + 1) \right) (1 + \phi)) - \gamma W_m \right) \right)$$

where

$$\hat{\sigma}_j = \hat{\sigma}_{j|f} s_f = \frac{\exp(\hat{\delta}_j/(1 - \hat{\sigma}))}{\hat{D}_f} \frac{\hat{D}_f^{1 - \hat{\sigma}}}{\sum_g \hat{D}_g^{1 - \hat{\sigma}}} , \hat{D}_f = \sum_{j \in f} \exp(\hat{\delta}_j/(1 - \hat{\sigma}))$$

Table: Summary statistics - Demand

VARIABLES	LPG	CNG	DIESEL	GASOLINE
price (thousands of €)	16.17 (4.11)	18.49 (5.93)	23.61 (9.04)	14.98 (6.11)
power/weight (kw/kg)	0.06 (0.01)	0.05 (0.01)	0.06 (0.01)	0.06 (0.01)
fuel cost (€/100 km)	6.08 (0.86)	4.29 (0.85)	8.33 (1.65)	9.96 (1.66)
acceleration (seconds)	12.99 (1.60)	13.40 (1.85)	11.99 (2.13)	12.98 (2.14)
length (cm)	400.42 (28.46)	403.59 (39.66)	427.66 (32.06)	391.07 (33.98)
(pump/kmsq)*100	1.90 (1.56)	0.77 (0.78)	11.86 (10.87)	12.50 (11.12)
CO2 emissions (g/km)	124.39 (16.98)	116.67 (14.48)	125.91 (24.67)	127.46 (20.89)
N. of observations	41091	12826	216326	131046
N. of variants	90	21	647	672



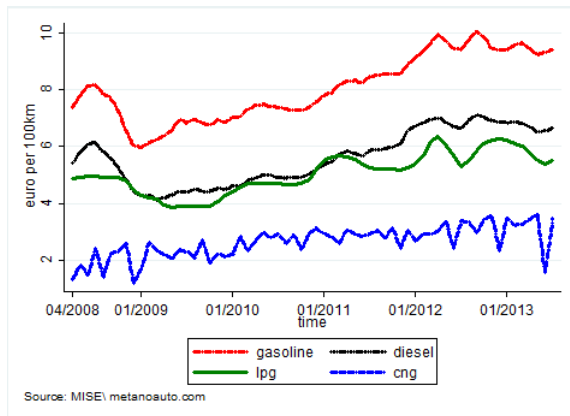
Table: Summary statistics - Entry

VARIABLES	LPG	CNG
fuel per car	1313.44 (790.82)	1492.57 (371.98)
land value	2.72 (0.00)	2.72 (0.00)
pumps	5.03 (8.72)	1.65 (3.03)
stock cars	2931.70 (8645.44)	1202.33 (2883.76)
Observations	611	572

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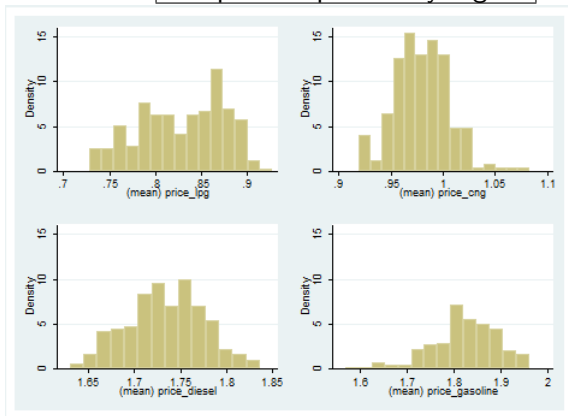
## Fuel cost for running 100km

- Average fuel efficiency for “compact” cars.
- Average fuel cost from 2008 until 2013.



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## Fuel price dispersion by regions



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Table: Number of filling station by company

	LPG	CNG	All
Eni	20%	20%	20%
Esso	9%	5	12%
IP	12%	8%	17%
Q8	8%	4%	11%
Tamoil	6%	4 %	7%
Totalerg	10%	6%	13%
Independent	22 %	43%	11%

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Table: Market characteristics.

Variable	mean	sd	p5	p25	p50	p75	p95
Population	97272.9	258292.5	6988	21890	45032	87339	280661
Surface	494.3916	403.4767	102.05	243.44	389.74	624.33	1283.44
LPG pumps	5.031097	8.717084	0	1	2	6	18
CNG pumps	1.540098	2.963651	0	0	0	2	6
Diesel pumps	33.39607	70.73615	3	8	18	34	91
Gasoline pumps	33.44845	71.03337	3	8	18	34	91

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Table: Robustness check: Distance.

VARIABLES	(1) IV Logit	(2) IV Logit density instruments	(3) IV Nested Logit	(4) IV Nested Logit density instruments
price	-0.11 (0.0119)	-0.16 (0.0093)	-0.11 (0.0071)	-0.11 (0.0072)
sigma			0.27 (0.011)	0.26 (0.011)
log(power/weight)	5.76 (2.320)	0.05 (1.835)	10.09 (1.369)	10.29 (1.386)
log(euro/100km)	0.06 (0.0066)	0.05 (0.0065)	0.04 (0.0049)	0.04 (0.0049)
log(acceleration)	0.09 (0.115)	0.48 (0.093)	0.33 (0.069)	0.34 (0.070)
log(length)	0.02 (0.008)	0.05 (0.007)	0.03 (0.005)	0.03 (0.005)
lpg*pump/kmsq	0.16 (0.007)	0.19 (0.008)	0.19 (0.005)	0.21 (0.006)
cng*pump/kmsq	0.54 (0.021)	0.59 (0.024)	0.60 (0.016)	0.64 (0.018)
diesel*pump/kmsq	-0.00 (0.001)	-0.00 (0.001)	-0.00 (0.000)	-0.00 (0.000)
gasoline*pump/kmsq	0.01 (0.001)	0.01 (0.001)	0.01 (0.001)	0.02 (0.001)
$R^2$	0.58	0.56	0.76	0.75
mean elasticity	-2.46	-3.40	-3.31	-3.33

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Table: Demand estimation

	IV 2Nested Logit	IV 2NL instrument distance
	(1)	(2)
Price (thousands of €)	-0.0191*** (0.00300)	-0.0122*** (0.00287)
$0.5\sqrt{M/N} * AF$	-0.0962*** (0.00373)	-0.308*** (0.0143)
$0.5\sqrt{M/N}$	-0.0625*** (0.00352)	0.133*** (0.0133)
Power/weight (kw/kg)	2.580*** (0.480)	0.978** (0.466)
fuel cost (€/100 km)	-0.00436* (0.00258)	-0.00929*** (0.00251)
length (cm)	0.00172*** (0.000295)	0.000937*** (0.000287)
$\sigma_1$	0.914*** (0.00294)	0.888*** (0.00352)
$\sigma_2$	0.823*** (0.00682)	0.805*** (0.00765)
implied price elasticity	-4.54	-2.22
N	141000	141000

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$