Green Cars Adoption and the Supply of Alternative Fuels

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TSE

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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), Springel (2016), Li et al. (2016).

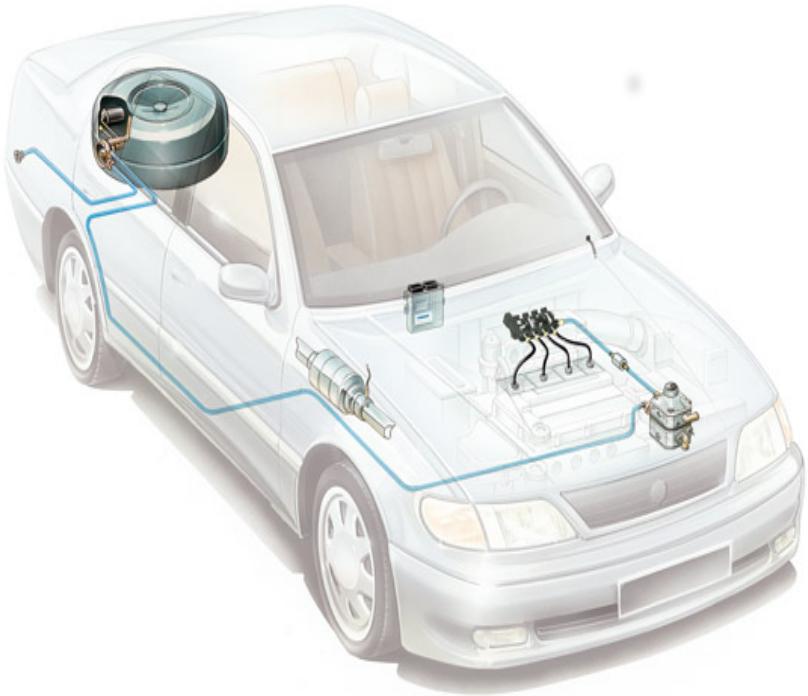
Demand of a durable good and supply of complementary goods

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

Models of Entry

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

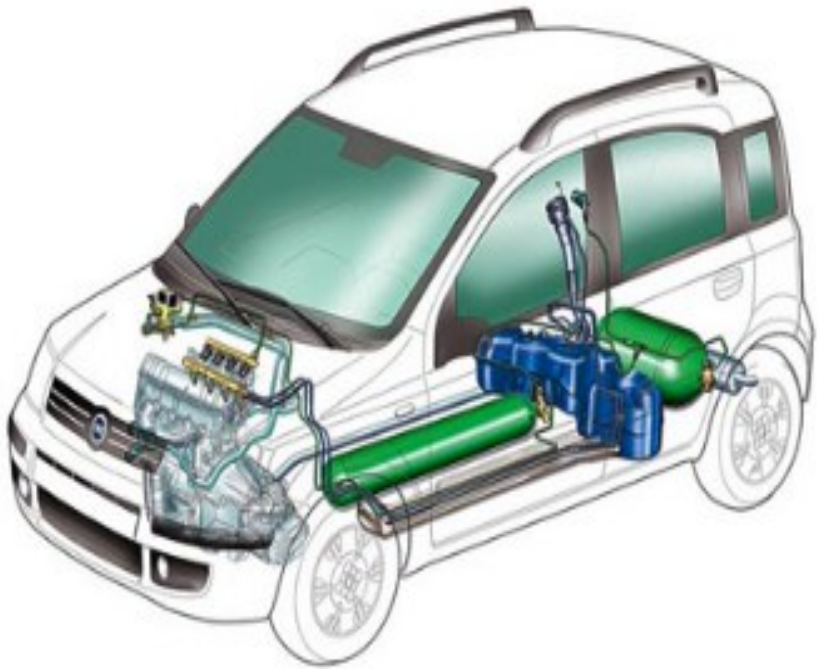
LPG vehicle



By-product of petroleum refining
or natural gas processing

Reduced life cycle GHG emissions by 10%
(98% to 99% if from NG production).

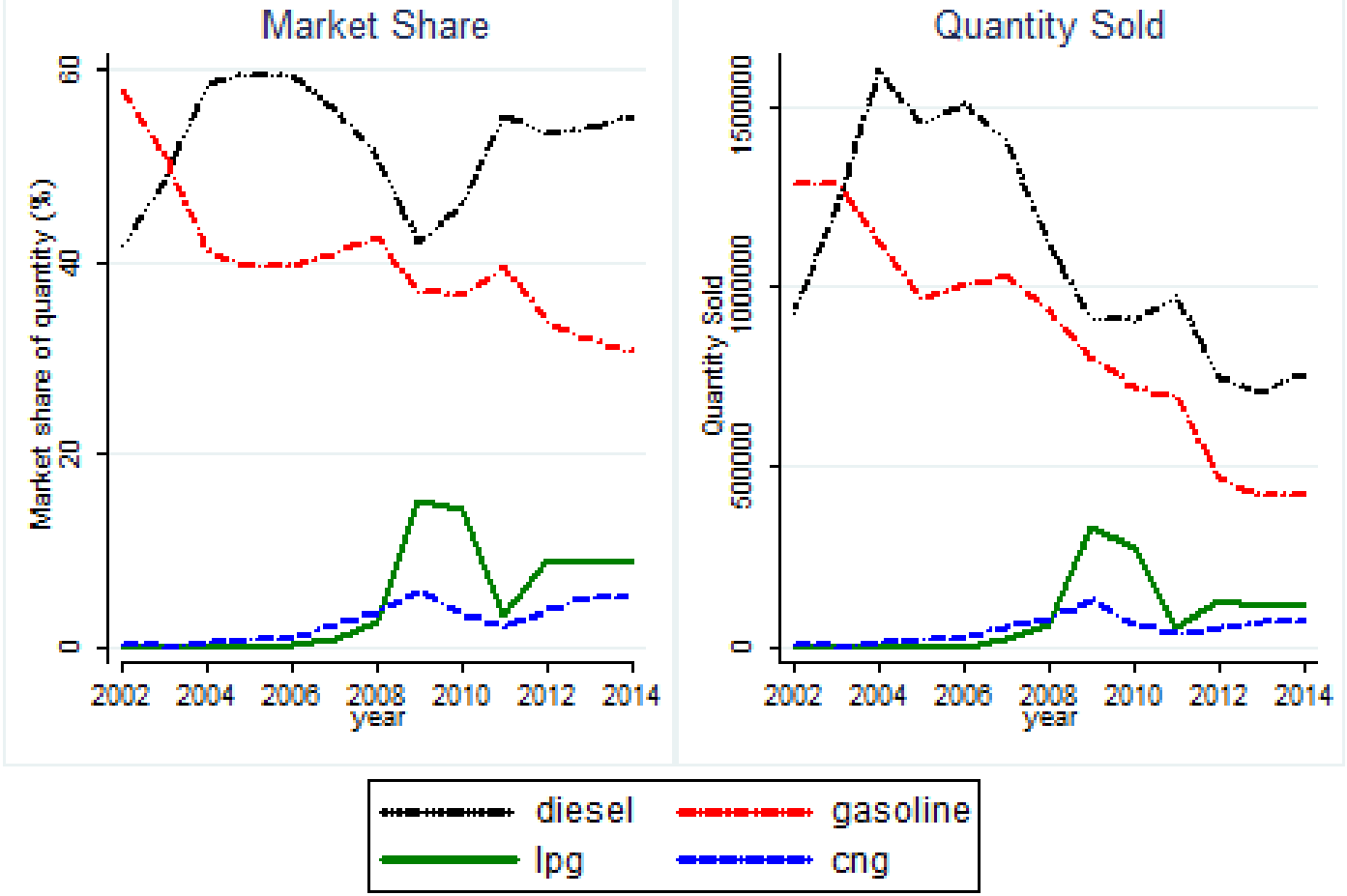
CNG vehicle



Underground reserves
and renewable biogas

Reduce life cycle GHG emissions by 11%
(83% if running on RNG).
Produce no evaporative emissions.

Vehicles by type of fuel. Italy 2002-2014



Source:ACI

▸ (Filling station) ▸ (Producers) ▸ (Segments)

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)

▸ (Market characteristics.)

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.
  - .
- Prices of fuels from ecomotori.net and ISTAT
  Price at province level.
  -

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 consumption 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, segment.
- Indirect utility:

$$u_{hj(f)m} = \delta_{j(f)m} + \nu_{hj(f)m}$$
$$\delta_{j(f)m} = \alpha p_{j(f)} + x_{j(f)}\beta + n_{fm}\lambda_h + \xi_{j(f)m}$$
$$\nu^h_{j(f)m} = \varepsilon^h_{fm} + (1-\sigma_2)\varepsilon^h_{sfm} + (1-\sigma_1)\varepsilon^h_{jm}$$

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

Demand: Estimation and Identification

- Estimating equation:

$$\ln\left(\frac{s_{j(f)m}}{s_{0m}}\right) = \alpha p_{j(f)m} + x_{j(f)m}\beta + n_{fm}\lambda + \sigma_1 \ln s_{j(f)|sfm} + \sigma_2 \ln(s_{s|fm}) + \xi_{j(f)}$$

  $s_{j(f)|sfm}$ is the market share of product $j(f)$ in the segment s installing fuel f

  $s_{s|fm}$ is the market share of segment s cars installing 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:
  - function of characteristics (same group/other group);
  - demand shifters per fuel due to local legislation.
- Instruments for alternative fuel density:
  - number of connections to the pipeline
  - distance from refineries producing LPG

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:
   $VP_m(n) - F_m \geq 0$ and $VP_m(n) - F_m \leq 0 \rightarrow$ conditions hold at mkt level.
4. Zero profit condition bounds:

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

5. Estimate by maximum likelihood.

Table : Demand Results

	IV 2Nested Logit	IV 2NL instrument density
	(1)	(2)
Price (thousands of €)	-0.018***	-0.012***
	(0.0029)	(0.0028)
$\log(N/M) * AF$	0.37***	0.65***
	(0.006)	(0.02)
$\log(N/M)$	0.034***	-0.014***
	(0.002)	(0.005)
Power/weight (kw/kg)	2.49***	1.53***
	(0.47)	(0.45)
fuel cost (€/100 km)	-0.005*	-0.007***
	(0.002)	(0.002)
length (cm)	0.002***	0.002***
	(0.0003)	(0.0003)
σ_1	0.92***	0.91***
	(0.003)	(0.003)
σ_2	0.83***	0.83***
	(0.007)	(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	7.20
	(0.40)	(0.56)
ln(pop)	0.33	0.35
	(0.03)	(0.05)
mandatoryAF	0.13	0.04
	(0.06)	(0.09)
north-east	-0.16	0.48
	(0.09)	(0.11)
center	-0.07	0.84
	(0.09)	(0.11)
south	-0.14	0.29
	(0.09)	(0.11)
islands	-0.25	-0.27
	(0.09)	(0.16)
cost shifter	-0.03	0.05
	(0.04)	(0.07)
ω	0.60	0.63
	(0.02)	(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

- 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

	Price Rebate			Filling station subsidy		
	Avg (% Δ)	5^{th} percentile (%Δ)	95^{th} percentile (% Δ)	Avg (% Δ)	5^{th} percentile (%Δ)	95^{th} percentile (% Δ)
			Direct effect			
			Car purchases			
Subsidized	**0.05**	**0.00**	**0.00**			
Others	-0.05	0.00	0.00			
			Pump density			
				89.56	0.00	173.66
			Overall effect			
			Car purchases			
Subsidized	**0.04**	**0.00**	**0.00**	**1.18**	**0.00**	**-1.31**
Others	-0.05	0.00	0.00	-1.22	-0.25	-1.70
			Pump density			
	0.12	0.00	0.00	111.23	0.00	251.97

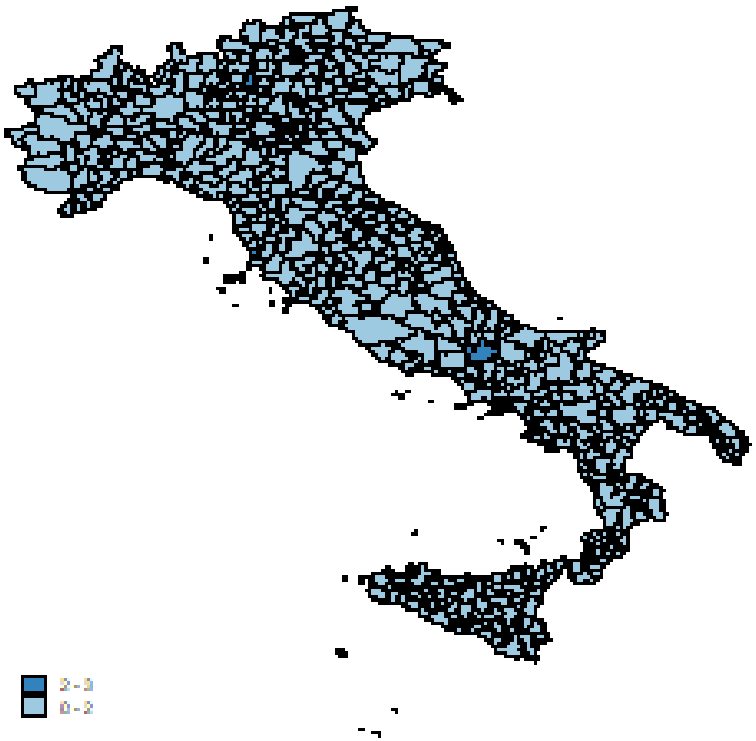
CNG

	Price Rebate			Filling station subsidy		
	Avg (% Δ)	5^{th} percentile (%Δ)	95^{th} percentile (% Δ)	Avg (% Δ)	5^{th} percentile (%Δ)	95^{th} percentile (% Δ)
			Direct effect			
			Car purchases			
Subsidized	**1.93**	**0.00**	**2.27**			
Others	-0.03	0.00	0.00			
			Pump density			
				60.08	0.00	166.50
			Overall effect			
			Car purchases			
Subsidized	**1.86**	**0.00**	**5.74**	**33.89**	**0.00**	**95.46**
Others	-0.03	0.00	-0.05	-0.55	-0.00	-1.30
			Pump density			
	0.13	0.00	2.82	79.23	0.00	275.77

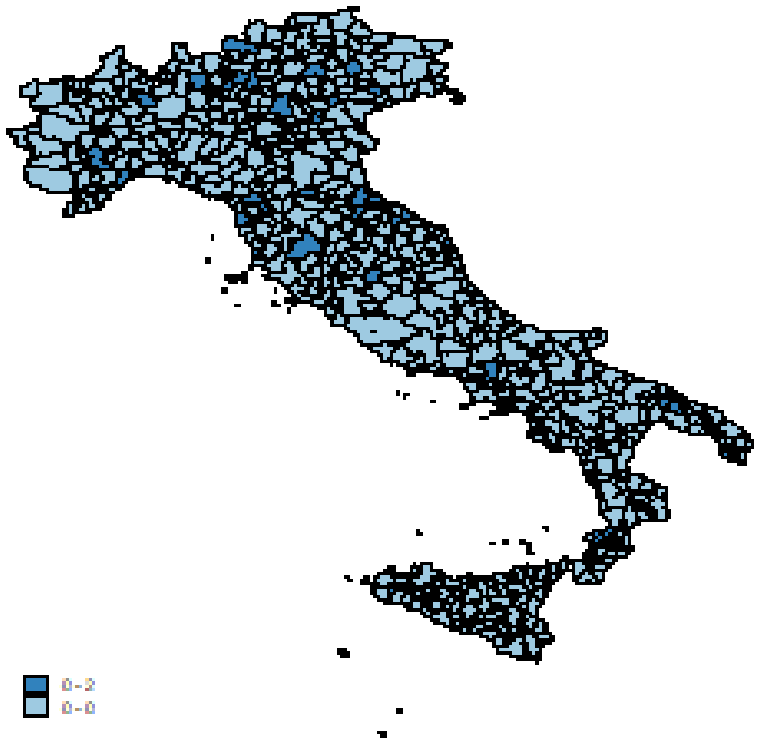
Policy comparison: Market level

Car price rebates

Market share variation



Filling station variation

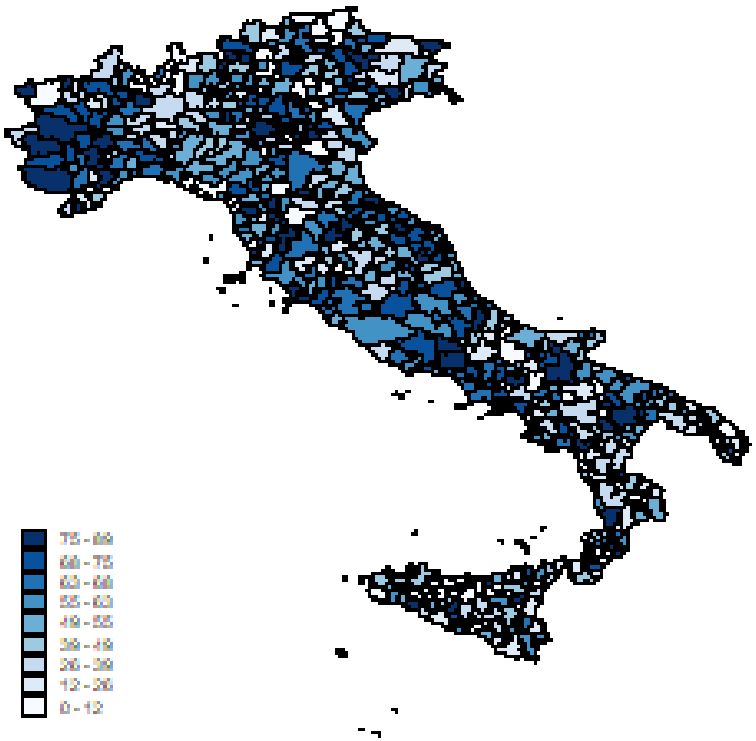


LPG

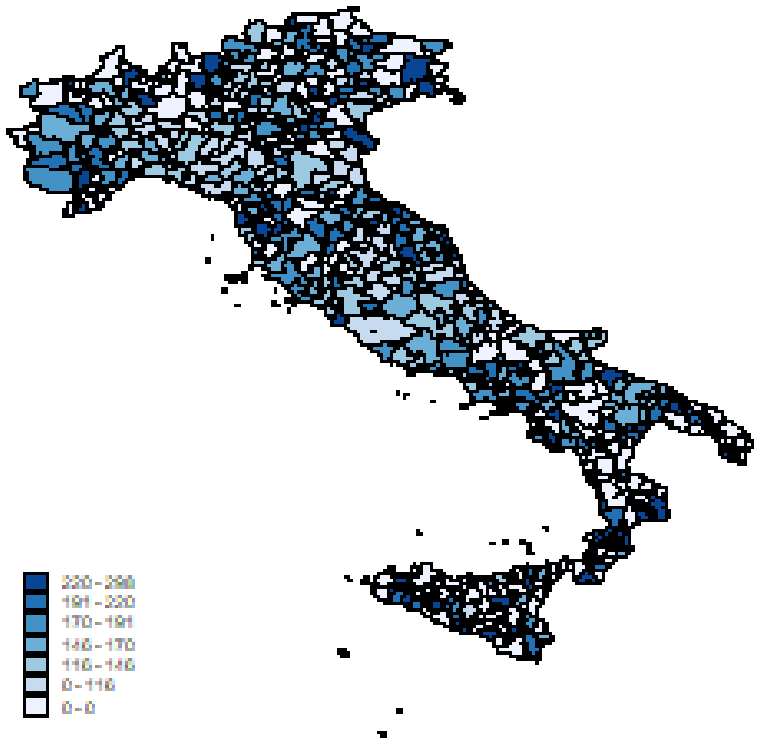
Policy comparison: Market level

Filling station subsidies

Market share variation



Filling station variation



LPG

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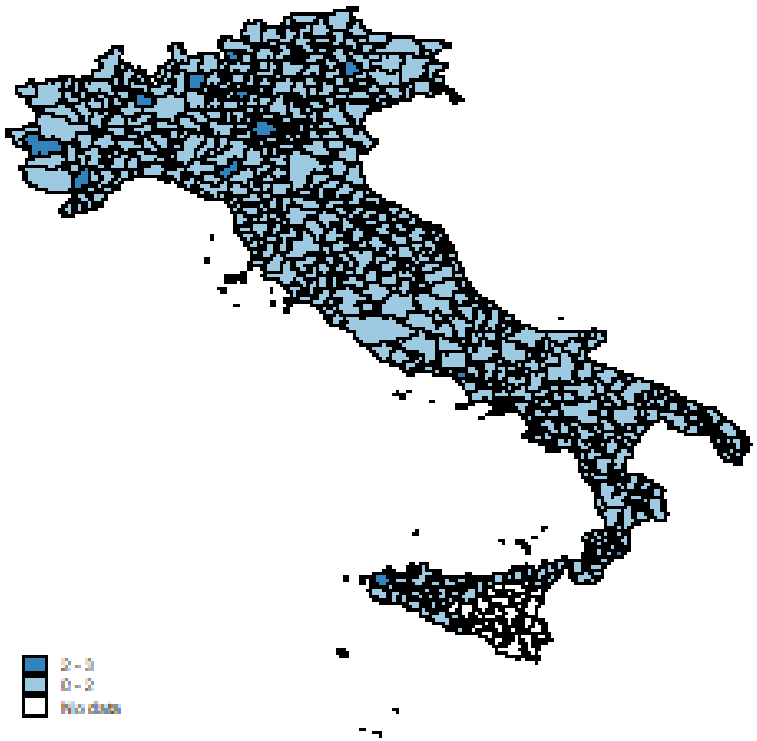
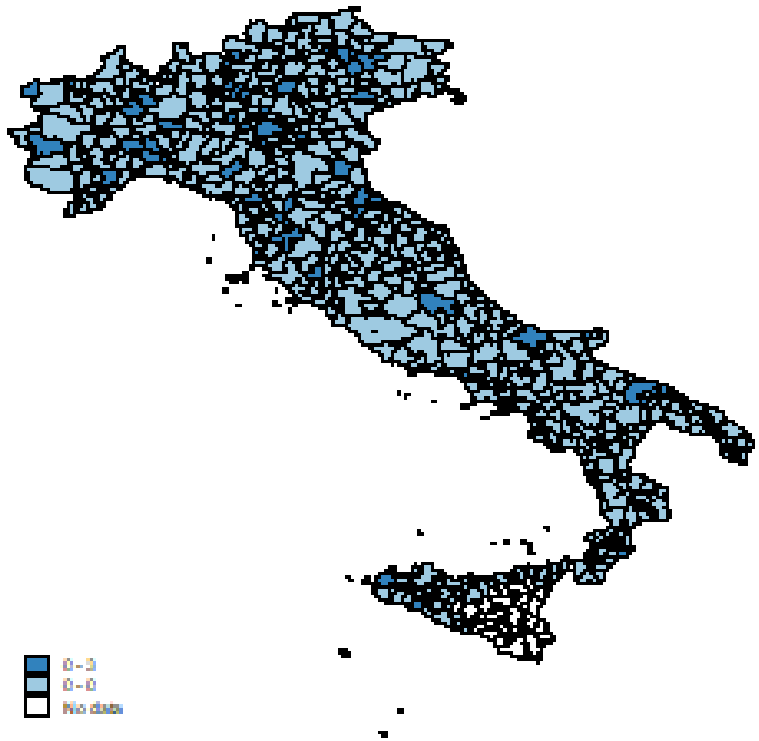


Filling station variation

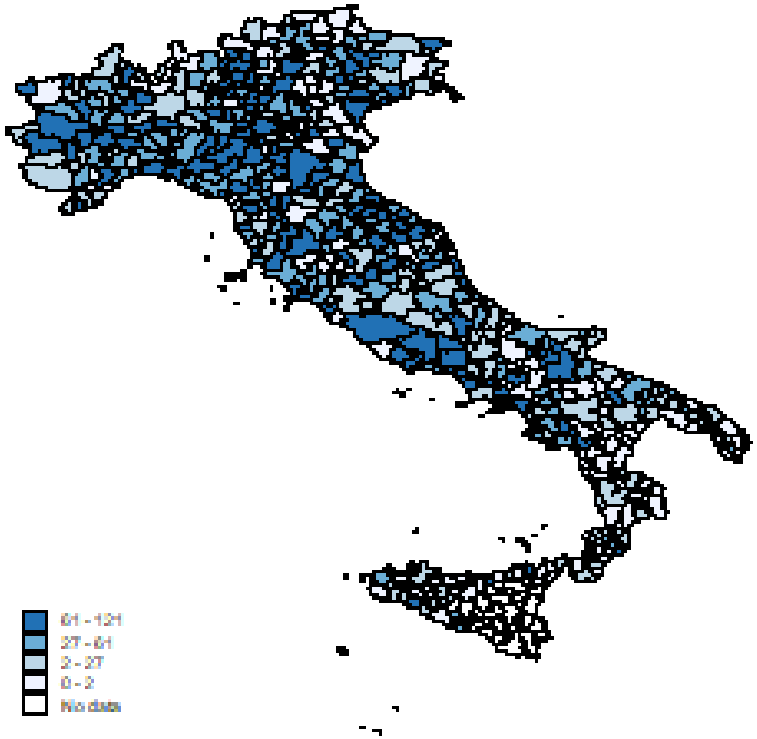


CNG

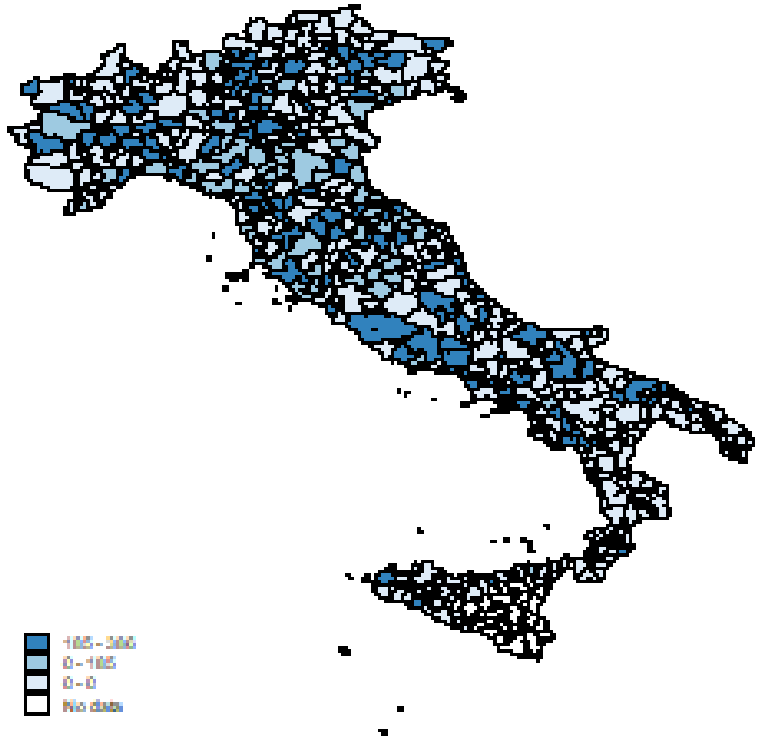
Policy comparison: Market level

Filling station subsidies

Market share variation



Filling station variation



CNG

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	0
Filling Station Subsidy	-0.22	-0.3

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	31.29	194.02
CNG	25.92	353.14
Traditional fuels	-0.16	-3.65

Conclusions

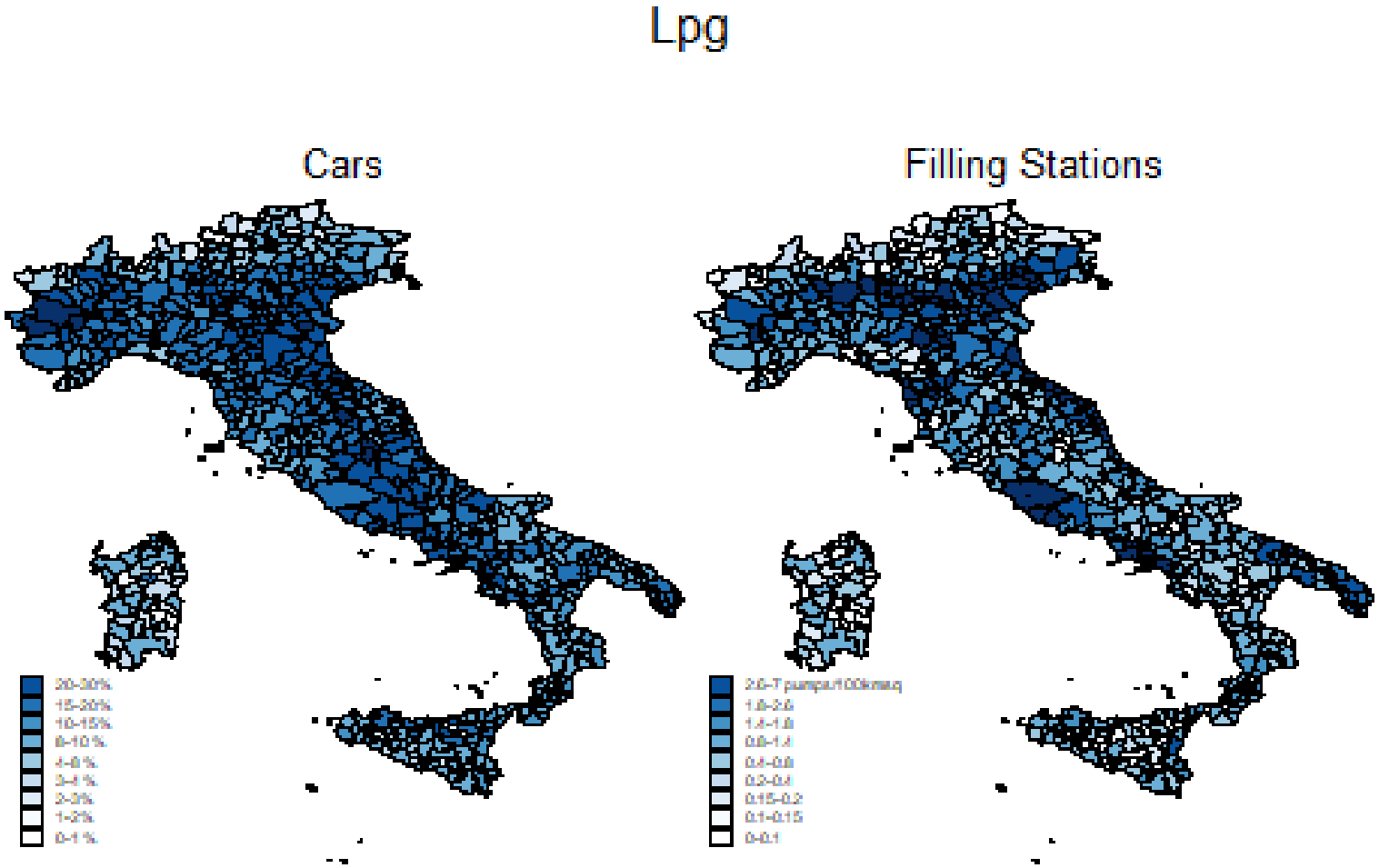
- Model the co-determination of AF vehicle demand and AF supply.
- Evidences of the crucial effect of the higher density of AF filling station on the choice of car adoption.
- Compare two policies acting on the two sides of the market.

	Price rebate	Filling station subsidy
Fostering the adoption of AF cars	effective 0 - 2%	effective 1-34%
Boosting AF pump installation	weak effect 0.1%	effective 100 - 80%
Environmental effect	low	medium
Long lasting effect	NO	YES

- Environmental effects(?)

Thank you.

Share of new cars 2012 and pumps location - LPG



Source:ACI and prezzibenzina.it

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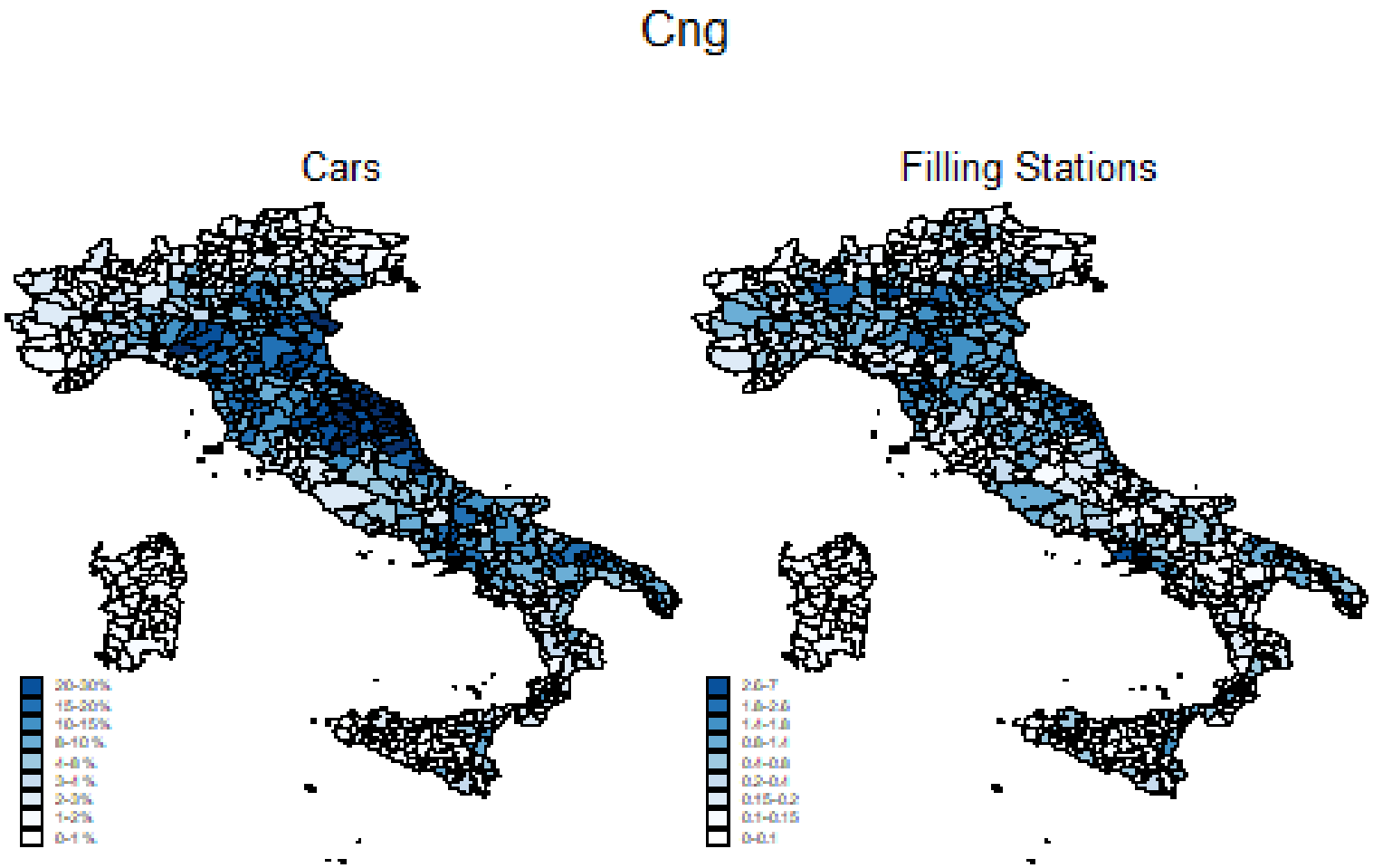
Share of new cars 2012 and pumps location - CNG



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.

Car builder group	Gasoline	Diesel	LPG	Natural gas
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%	

▸ (Back)

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

▸ (Back)

- Log-likelihood.

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

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

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

where

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

▸ (Back)

Table : Summary statistics - Demand

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

(Back)

Table : Summary statistics - Entry

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

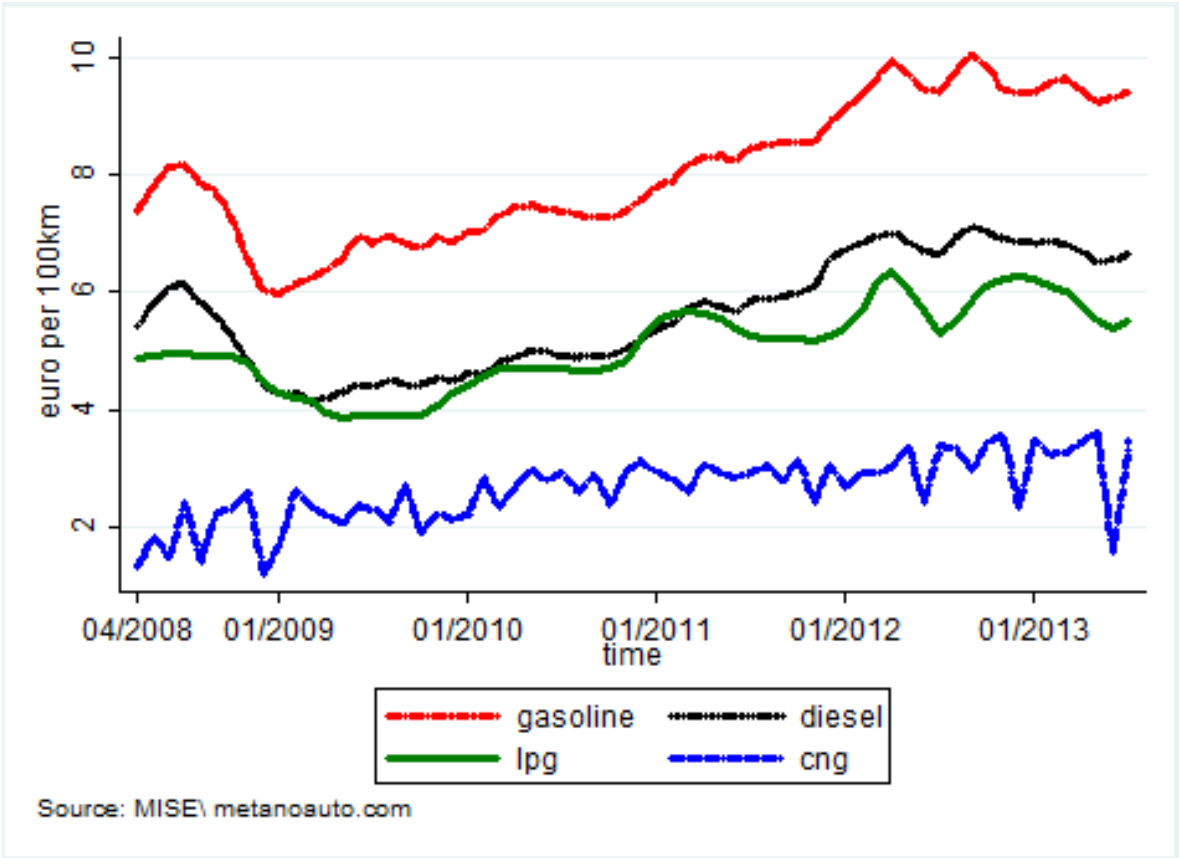

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Table : Number of filling station by company

	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%

(Back)

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

▸ (Back)

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

▸ (Back)

Table : Demand estimation

	IV 2Nested Logit	IV 2NL instrument distance
	(1)	(2)
Price (thousands of €)	-0.0191***	-0.0122***
	(0.00300)	(0.00287)
$0.5\sqrt{M/N} * AF$	-0.0962***	-0.308***
	(0.00373)	(0.0143)
$0.5\sqrt{M/N}$	-0.0625***	0.133***
	(0.00352)	(0.0133)
Power/weight (kw/kg)	2.580***	0.978**
	(0.480)	(0.466)
fuel cost (€/100 km)	-0.00436*	-0.00929***
	(0.00258)	(0.00251)
length (cm)	0.00172***	0.000937***
	(0.000295)	(0.000287)
σ_1	0.914***	0.888***
	(0.00294)	(0.00352)
σ_2	0.823***	0.805***
	(0.00682)	(0.00765)
implied price elasticity	-4.54	-2.22
N	141000	141000

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$