Strategic Entry and Policy in Isolated EV Charging Markets

Lydia Dimitrakopoulou

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Motivation

Electric Vehicle (EV) Adoption and Infrastructure

- The growth of EVs raises critical questions about charging demand, station competition, and infrastructure efficiency.
- Understanding consumer choice of charging stations is essential for:
  - Pricing strategy and investment decisions
  - Network planning and location optimization
  - Evaluating policy impacts (e.g. gasoline subsidies)

Related Literature

- Prior work (Springel (2021), Remmy (2022)) focuses on aggregate station deployment
- Limitation:
  1) Limited analysis of competition and policy effects like gasoline subsidies
  2) No estimation of station-level profitability

Contribution

- An empirical study of how a regulatory transport shock (the "40% battery rule") reshapes EV charging demand, pricing, and entry across isolated markets.
- Contribute to the literature on firm behavior in isolated markets:
  - Build on Bresnahan and Reiss (1991), Dimitrakopoulou et al. (2024) and Genakos and Pagliero (2022).
- Show how limited competition, exogenous demand shocks, and market-specific subsidies jointly influence infrastructure expansion.
- Offer the first evidence on the unintended effects of fuel subsidies on clean infrastructure:
  - Show how gasoline subsidies distorted prior investment incentives—but amplified responses to EV-targeted regulation.

Policy Shock: EV Charging Restriction (May 2024)

"40% Battery Rule" — Maritime Transport Ban

On May 1st, 2024, the Greek government introduced a safety regulation: Electric vehicles (EVs) with more than 40% battery charge were prohibited from boarding ferries.

Empirical Relevance

- Introduces a sharp and exogenous demand shock for public charging on affected islands.
- Enables a natural experiment to study policy-driven shifts in both consumer behavior and infrastructure deployment.
- Interacts with pre-existing gasoline subsidies, creating variation in firm responses across markets.

Data Collection and Sources

EV Charging Station Dataset

- Constructed a novel, high-frequency dataset of all public EV charging stations in Greece.
- Collected daily price and charging duration data since April 24th, 2024.
- Covers the full universe of stations across Greek islands and the mainland.
- Includes detailed technical and locational attributes: power rating, voltage, connector type, geographic coordinates.

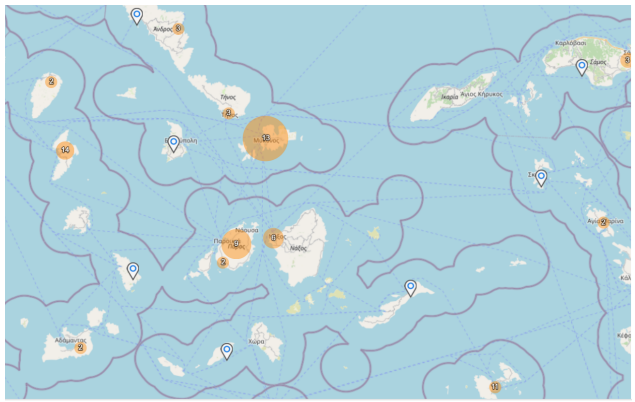
Greek Islands as Isolated Markets

Empirical Setting:

The Greek islands offer a unique environment to study EV infrastructure:

- Isolated markets — no arbitrage across islands.
  - Genakos and Pagliero (2022)
  - Dimitrakopoulou et al. (2024)
- Captive demand — EV users must rely on local charging infrastructure.
- Natural variation in market size, competition, and subsidy exposure.

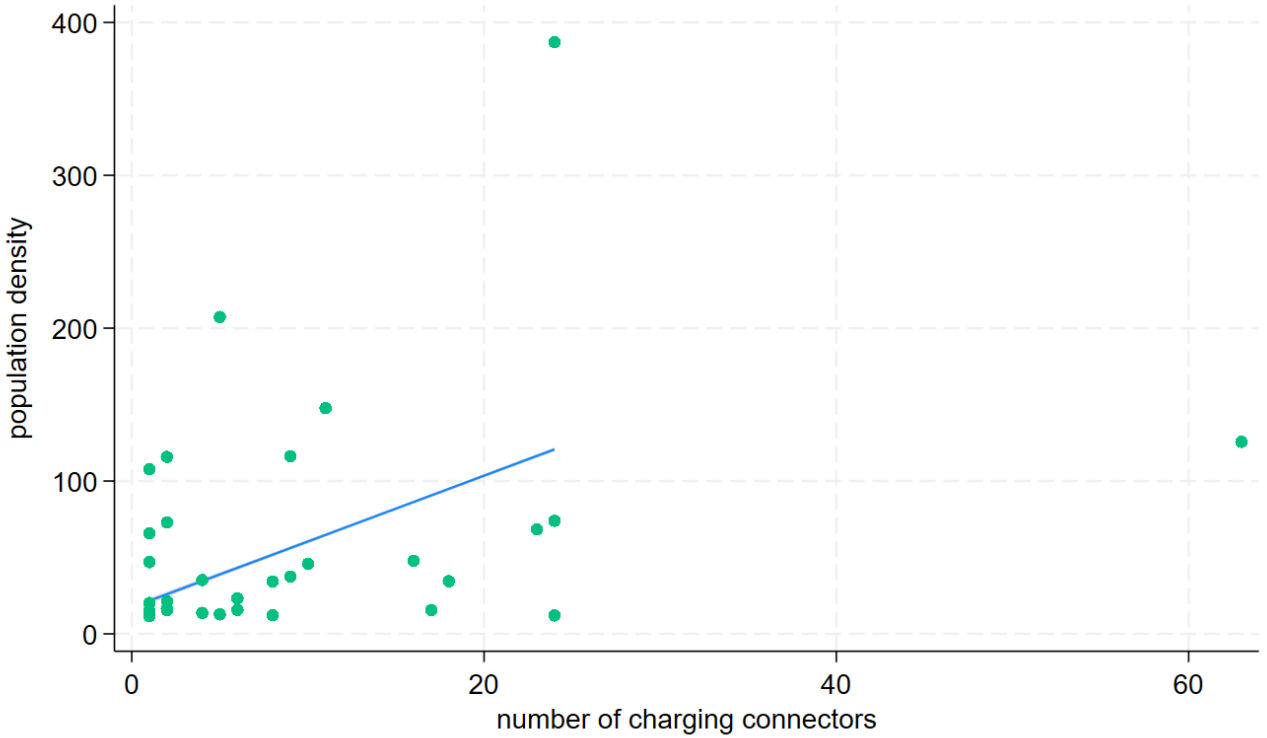
Sample: 30 inhabited islands with public EV chargers. Some receive gasoline subsidies, others do not.



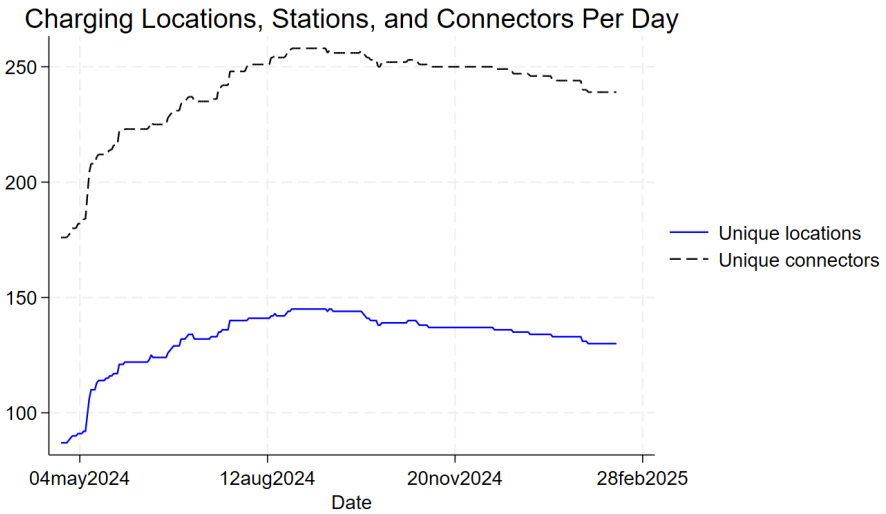
Population Density on Greek Islands

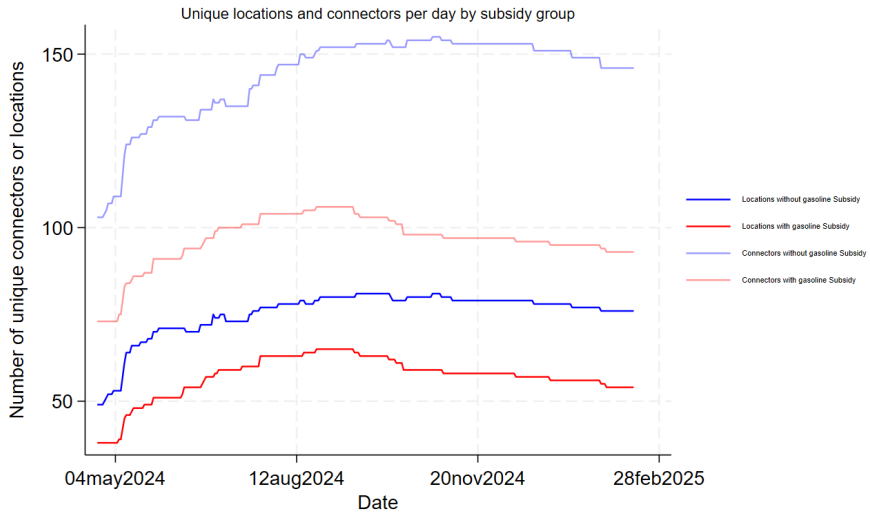
Island	With Gasoline Subsidy	Island	Without Gasoline Subsidy
Astypalaia	12.06	Andros	23.23
Kythira	12.15	Thasos	34.48
Chalki	12.82	Tinos	45.93
Skyros	13.68	Naxos	47.86
Samothraki	14.58	Samos	68.37
Kimolos	15.20	Paros	73.97
Amorgos	15.52	Kos	125.60
Kythnos	15.65	Aegina	147.71
Kea	15.68	Syros	207.30
Serifos	16.50	Salamina	387.06
Karpathos	20.22		
Ios	21.29		
Limnos	34.36		
Milos	35.21		
Sifnos	37.56		
Skopelos	46.95		
Patmos	72.96		
Leros	107.75		
Ammouliani	115.78		
Skiathos	116.28		

Unique Connectors Across Markets

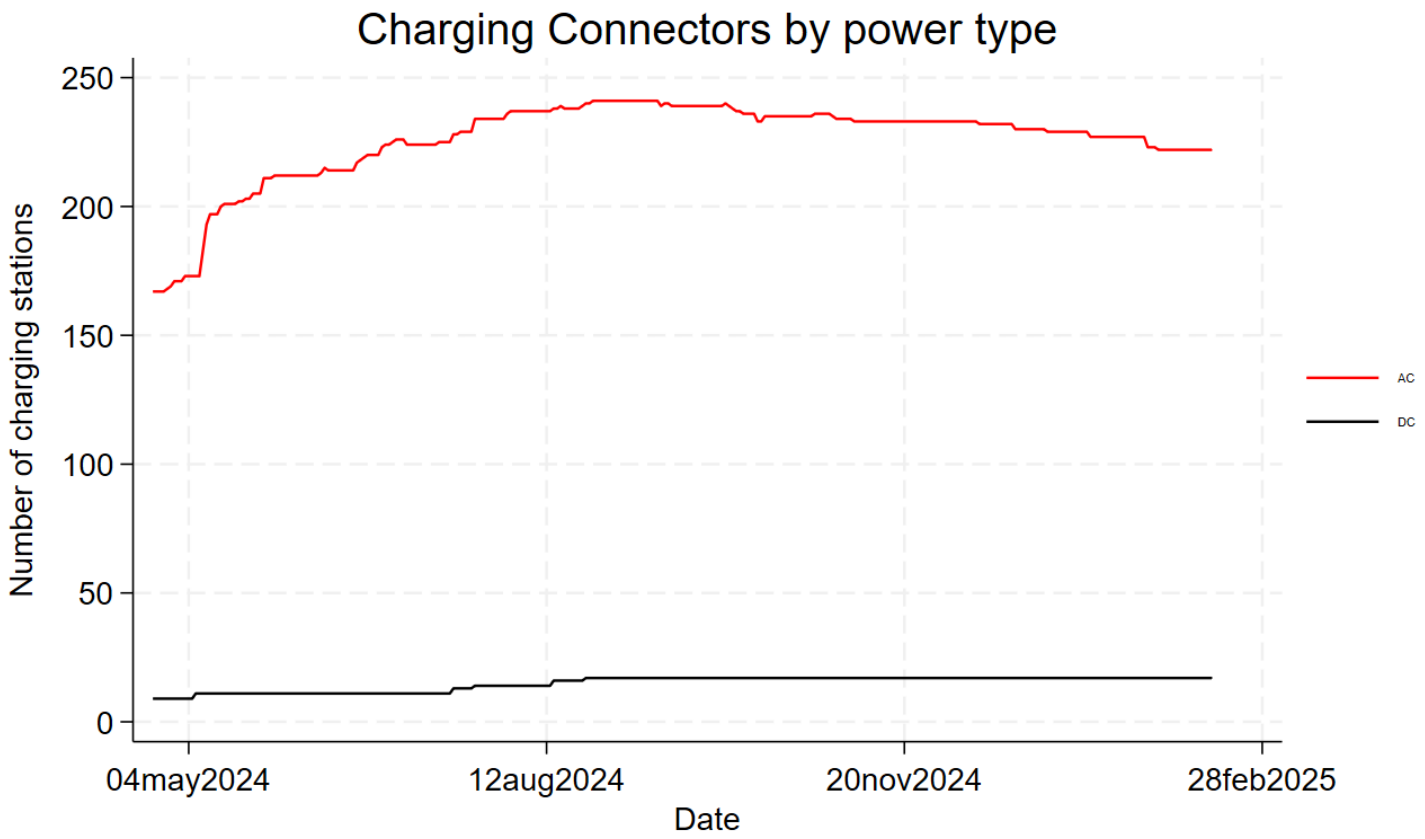


Number of charging locations, stations and connectors per day

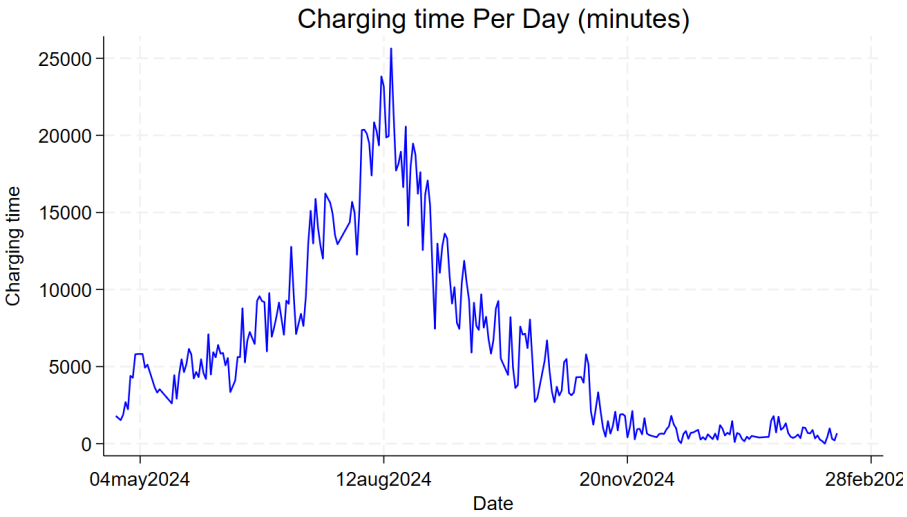




Charging stations by power type



Charging time per day



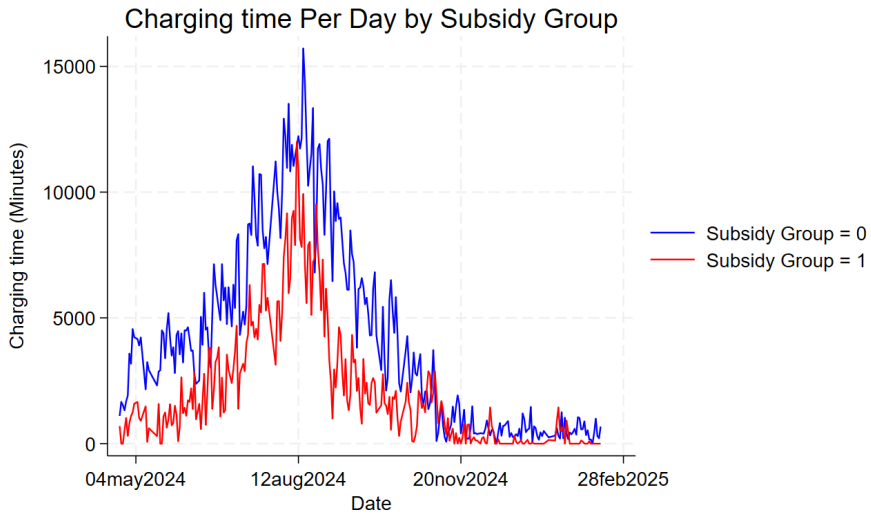


Table: Summary Statistics of Price by Connector

Statistic	ENERGY	FLAT
Observations	72,207	126
Mean	0.450	0.988
Std. Dev.	0.065	0.052
Variance	0.004	0.003
Percentiles		
1%	0.35	0.865
5%	0.35	0.865
10%	0.4	0.865
25%	0.42	1.01
50%	0.425	1.01
75%	0.5	1.01
90%	0.55	1.01
95%	0.6	1.01
99%	0.615	1.01

Effect of Price on Energy Delivered and Revenues

	(1) Energy per Day	(2) Daily Revenues
Price per Charging Connector	-745.55^{***}	-390.25^{***}
	(196.37)	(82.71)
Competition (Connectors)	3.21^{*}	1.39^{*}
	(1.72)	(0.80)
HHI	0.0003^{**}	0.0001^{**}
	(0.0001)	(0.0001)
Number of Tourists	0.0002^{***}	0.0001^{***}
	(0.0001)	(0.0000)
Constant	265.71^{**}	144.89^{**}
	(128.70)	(55.18)
Observations	51,324	51,324
R-squared (within)	0.0042	0.0046

Standard errors in parentheses, clustered by island. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Competition is measured as the number of connectors per island-week.

Effect of Post-Shock Period on Charging Station Outcomes

	(1) Price	(2) Revenues	(3) Energy	(4) Competition	(5) HHI
Shock	-0.0002^{***}	17.24^{***}	40.74^{***}	0.221^{***}	8197.88^{***}
	(0.0000)	(1.36)	(3.36)	(0.023)	(274.17)
Observations	51,324	51,324	51,511	51,511	51,511
R-squared (within)	0.0007	0.0031	0.0029	0.0018	0.0171

Standard errors in parentheses, clustered at the island level.

$^{***}p < 0.01$. The shock dummy equals 1 post-regulation.

Structural Model: EV Charging Market

Overview:

We estimate a structural model of the EV charging market that links consumer demand, firm pricing, and entry decisions.

- Demand is modeled using a logit discrete choice framework with an outside option, following Berry (1994).
- The estimated demand system enables recovery of price elasticities, marginal costs, and implied markups under Bertrand pricing.
- These estimates feed into a firm-level entry model, which incorporates market structure, cost conditions, and policy shocks.

Demand Specification and Identification

Consumer utility:

$$U_{ijmt} = \delta_{jmt} + \varepsilon_{ijmt}, \quad \text{with} \quad \delta_{jmt} = X_{jmt}\beta - \alpha p_{jmt} + \xi_{jmt}$$

Market share equation:

$$s_{jmt} = \frac{\exp(\delta_{jmt})}{1 + \sum_{k \in J_{mt}} \exp(\delta_{kmt})}$$

Estimating equation (logit inversion):

$$\log\left(\frac{s_{jmt}}{s_{0mt}}\right) = X_{jmt}\beta - \alpha p_{jmt} + \xi_{jmt}$$

Identification strategy: Price p_{jmt} is instrumented using the average price of the same operator in other islands, following a Hausman-type approach. This helps address price endogeneity arising from unobserved demand shocks ξ_{jmt}.

Logit Demand Estimation for Public Charging

Dependent Variable	(1) OLS $(\log(s_j/s_0))$	(2) IV $(\log(s_j/s_0))$
Price per kWh	-20.12^{***}	-4.39^{***}
	(4.77)	(1.12)
Competition (Connectors)	-0.032^{***}	-0.070^{***}
	(0.0053)	(0.0010)
Constant	1.94	-4.24^{***}
	(2.11)	(0.51)
Instrument	–	Avg. Price in Other Islands
First-Stage F-Stat.	–	1681.76
Observations	51,324	51,324
R-squared (within)	0.0011	0.1265

Standard errors in parentheses. *** $p < 0.01$.

IV uses average price in other islands as instrument.

Recovering Elasticities and Marginal Costs

Step 1: Own-Price Elasticity

$$\epsilon_{it} = \alpha \cdot P_{it} \cdot (1 - \text{market share}_{it})$$

Step 2: Marginal Cost, Markup and Variable profits

$$MC_{it} = \frac{P_{it}}{1 + \frac{1}{\epsilon_{it}}}, \quad \text{Markup}_{it} = (P_{it} - MC_{it})/P_{it}$$

$$\text{Variable Profits}_{it} = (P_{it} - MC_{it}) \cdot Q_{it}$$

Price vs. Marginal Cost

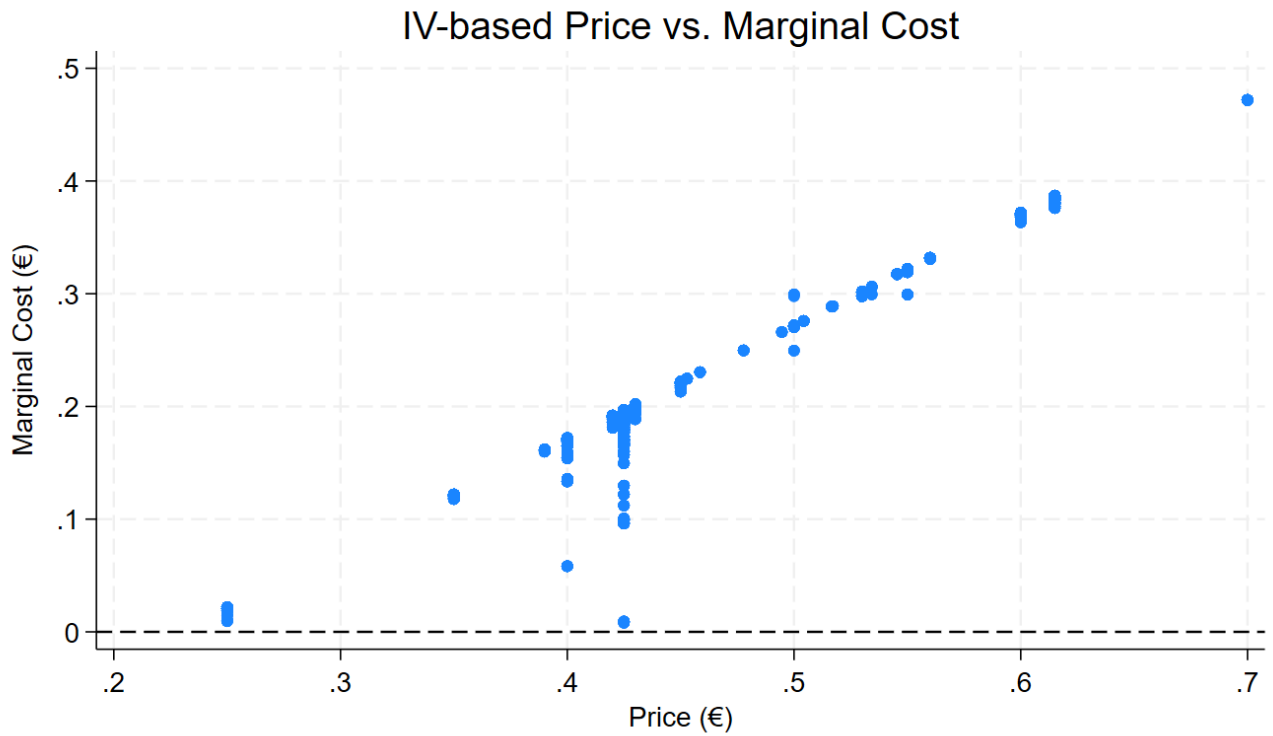


Figure: Price vs. Estimated Marginal Cost at the Connector Level

- Prices closely track marginal costs across stations, suggesting:
  - Limited dispersion in cost structures.

Estimated Markup at the Connector Level

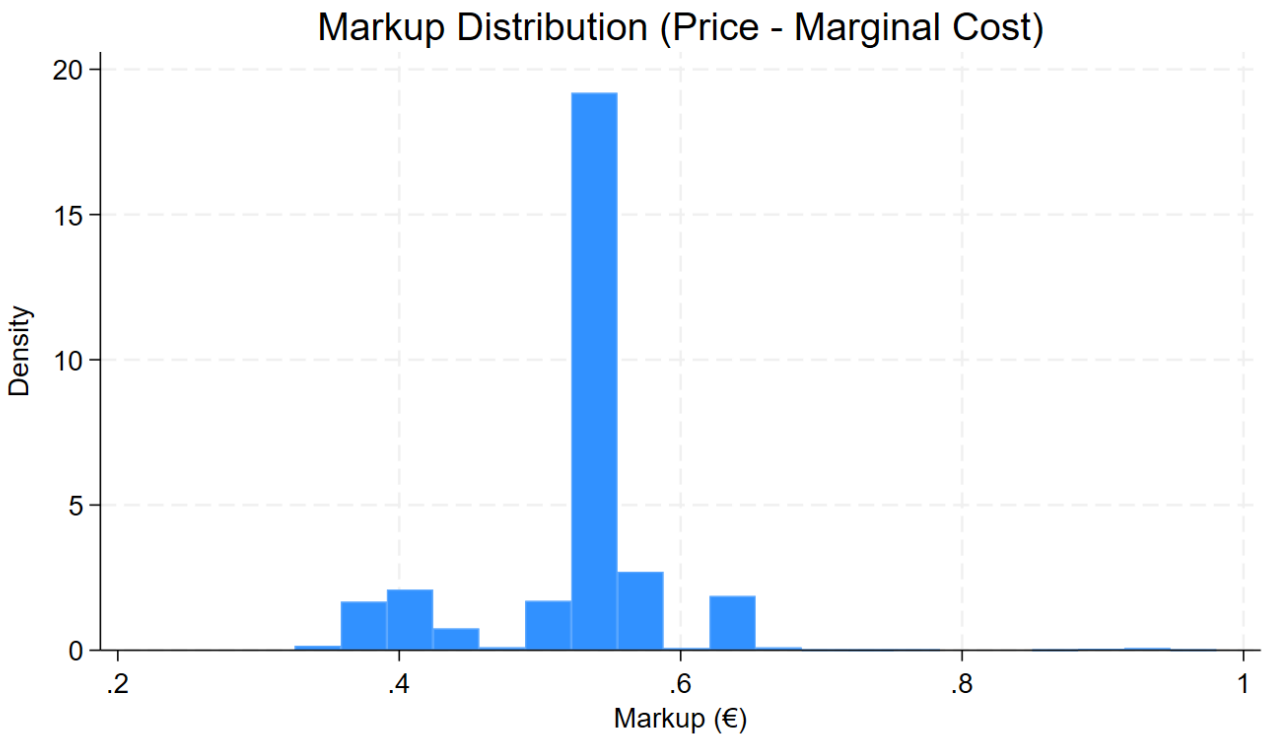


Figure: Estimated Markup at the Connector Level

Entry Model: Discrete Choice Framework

Entry Decision:
We estimate a binary discrete choice model of station entry, where firms decide whether to install a new connector based on expected profitability and market conditions.

Specification:

$$\Pr(\text{entry}_{jt} = 1) = \Lambda\left(\gamma_0 + \gamma_1 \cdot \text{markup}_{jt}^{IV} + \gamma_2 \cdot \text{subsidy}_m + \gamma_3 \cdot \text{competition}_{jt} + \gamma_4 \cdot \text{HHI}_{mt}\right)$$

- Estimated via logistic regression on station-week panel data.
- markup: Instrumented markup from demand estimation (logit + IV).
- subsidy: Indicator for availability of gasoline subsidy in the market.
- competition: Number of connectors in the market.
- HHI: Herfindahl-Hirschman Index measuring local market concentration.

Entry Model Estimates: Discrete Choice (Logit)

Dependent Variable	(1) Entry (=1 if new connector installed)
Markup (IV)	-11.99^{***}
	(0.18)
Government Subsidy	0.544^{***}
	(0.027)
Competition (Connectors)	0.0047^{***}
	(0.0008)
HHI (Market Concentration)	0.0000^{***}
	(0.0000)
Constant	5.04^{***}
	(0.093)
Observations	51,324
Pseudo R-squared	0.099

Standard errors in parentheses. *** $p < 0.01$.

Higher predicted markups reduce entry probability, consistent with zero-profit conditions under free entry.

Conclusion and Next Steps

Main Findings:

- Competition: Local competition significantly influence infrastructure expansion.
- Policy Shock: The "40% ferry rule" triggered a rise in charging demand, revenues, and subsequent entry on affected islands.
- Cross-market energy policies can generate unintended substitution or crowding-out effects.

Conclusion and Next Steps

Next Steps:

- Simulate counterfactuals: no gasoline subsidy or free entry.
- Explore richer and more exogenous instruments for price decisions.

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