

# Electric Vehicles and Consumer Choices

Filip Mandys  
University of Surrey

16<sup>th</sup> IAEE European Conference

26<sup>th</sup> August 2019



- Electric vehicles (EVs) have significant benefits compared to conventional vehicles (CVs). These benefits include:
  - **Economic** – lower operating costs due to higher fuel efficiency.
  - **Environmental** – lower greenhouse gas emissions and pollution per km.
  - **Health** – lower local health risks.
- However, the market share of EVs in the UK remains low.
- The benefits will not be realized unless the government and the manufacturers can gain crucial information in order to optimize their strategies and speed up the adoption of EVs.

- **Question 1:** What are the most important characteristics and attributes of potential EV consumers in the UK.
- **Question 2:** Which vehicle characteristics chiefly affect the consumers' desire to buy EVs.
- **Question 3:** What are the largest barriers to EV adoption for the potential EV consumers in the UK.

To the best of my knowledge, no previous study has investigated these questions for the UK market.

This information is crucial to manufacturers for optimal design purposes, marketing and advertising strategies.

Governments also highly value this information for policy and educational purposes, or for support programs targeted at specific typology of consumers.

- I use the Electric Vehicle Module of the Opinions and Lifestyle Survey.
- The Opinions and Lifestyle Survey is a multipurpose social survey, carried out by the Office of National Statistics.
- The Electric Vehicle Module is a more topic-specific set of questions, included into the core demographic questions of the Opinions and Lifestyle Survey.
  - Information about the respondents' vehicle buying priorities and their considerations of purchasing an EV vs a CV is available.

- The data is a pooled-cross section with two time periods, i.e. 2014 and 2015.
- It includes UK adults aged 16 years and older, living in private households.
- Information on consumer profile attributes (age, education, etc.) and vehicle attributes (rating of performance, ease of EV recharging, etc.) is included.
- The data, and thus the results of the paper, are based on stated preferences.

- Y is constructed from the following question: *Which statement best describes your attitude towards buying an electric car?*
- For Questions 1 and 2:
  - Y=1 if individual thought of buying an EV (potential EV adopter)
  - Y=0 if individual have not thought of buying an EV
- For Question 3:
  - Y=1 if individual thought of buying an EV, but decided not to at that point in time (temporarily discouraged potential EV adopter)
  - Y=0 otherwise

# The Estimating Sample

- The full data contains 1996 observations. The estimating sample contains 1347 observations (questions 1 and 2), and 65 usable variables.
  - Consumer profile attributes include: *age, gender, education, income, etc.*
  - Vehicle attributes include: *comfort, environmental impact, price, performance, reliability, safety, etc.*
- The number of observations decreases to 1154 for question 3.
  - Variables representing barriers to EVs include: *low maximum range, high purchase cost, lack of knowledge, etc.*

- The Adaptive Lasso estimator for variable selection is defined as:

$$\hat{\beta}_n^{AL} = \arg \min_u \sum_{j=1}^n (y_j - u'x_j)^2 + \lambda_n \sum_{i=1}^p \lambda_{n,i} |u_i|$$

$\lambda_n > 0$  = tuning parameter

$\lambda_{n,i} = \frac{1}{(|\hat{\beta}_{n,i}|)^\gamma}$  = adaptive weights vector

$\hat{\beta}_{n,i}$  = initial estimate of the coefficients

$\gamma$  = positive constant for adjustment of the adaptive weights vector, set between  $\frac{1}{3}$  and  $\frac{10}{3}$ .

$u_i$  = estimated coefficients

- Most important is the tuning parameter  $\lambda_n$ , found using 10 rounds of cross-validation.
  - The method shrinks the coefficient of those variables that are irrelevant for the research to zero.
  - Out of 65 variables, this method shrunk 39 variables to zero, resulting in 26 variables for regression.
- Binomial Logistic Regression:
    - Advantage: method is well established and provides intuitive inference on the coefficients.



- For finding the characteristics of potential EV adopters and the importance of vehicle attributes, the logit regression is as follows:

$$y_j = \beta_0 + \sum_{l=1}^L \beta_l z_{j,l} + \sum_{k=1}^K \alpha_k w_{j,k} + \sum_{r=1}^R \gamma_r c_{j,r} + \epsilon_j, \quad j = 1, 2, \dots, n$$

$y_j$  = EV dependent variable

$z_{j,l}$  = consumer profile attribute variables from adaptive Lasso

$w_{j,k}$  = vehicle attribute variables from adaptive Lasso

$c_{j,r}$  = control variables

$\beta_l$  = coefficients of the consumer variables

$\alpha_k$  = coefficients of the vehicle variables

$\gamma_r$  = coefficients of the control variables

$\epsilon_j$  = error term

$n$  = number of observations

$L$  = number of consumer variables

$K$  = number of vehicle variables

$R$  = number of control variables.

# Econometric Model (For Q. 3)

- In order to identify the key barriers to EV adoption for the potential EV buyers, the binomial logit regression is used:

$$q_d = \beta_0 + \sum_{b=1}^B \beta_b k_{d,b} + \sum_{r=1}^R \gamma_r c_{d,r} + \epsilon_d, \quad d = 1, 2, \dots, D$$

$q_d$  = dependent variable of discouraged potential EV adopters

$k_{d,b}$  = barrier variables from adaptive Lasso

$c_{d,r}$  = control variables of consumer profile attributes from adaptive Lasso

$\beta_b$  = coefficients of the barrier variables

$\gamma_r$  = coefficients of the control variables

$\epsilon_d$  = error term

$D$  = number of observations

$B$  = number of barrier variables

$R$  = number of control variables

- The consumer attributes found to be unimportant:
  - Year dummy
  - Nationality
  - Some regions of habitude
  - Type of accommodation ownership
  - Number of young children
  - Presence of disability
  - Full-time vs part-time job
  - Some occupation types.
- Vehicle attributes that were found to be insignificant:
  - Comfort
  - Interior size
  - Width of choice among CVs and EVs
  - Reliability
  - Overall establishment of technology
  - Maintenance cost
  - Vehicle tax
  - Resale value
  - Insurance cost

# Results: Consumer Attributes (Q. 1)

Thought of Buying an EV	Odds Ratio	Standard Error	P-value
Frequency of Public Transport Use	1.01	(0.035)	0.774
Frequency of Car Use	0.981	(0.051)	0.707
West Midlands	1.668	(0.402) **	0.034
East of England	1.457	(0.361) †	0.128
South East	1.203	(0.236)	0.347
South West	1.716	(0.43) **	0.031
Household Size	0.924	(0.066)	0.27
Male	1.193	(0.186)	0.258
Age ( <i>years</i> )	0.988	(0.006) **	0.036
Married	1.393	(0.231) **	0.046
Number of Vehicles	1.041	(0.112)	0.709
Degree Level	2.47	(0.726) ***	0.002
Higher Education	2.166	(0.71) **	0.018
A Levels	2.541	(0.845) ***	0.005
ONC	1.526	(0.636)	0.31
GCSE A-C	1.344	(0.413)	0.336
GCSE D-G	2.054	(0.891) *	0.097
Other/Foreign Qualification	1.949	(0.62) **	0.036
Health ( <i>Likert scale</i> )	0.875	(0.074) †	0.115
Lower Managerial/Professional	0.63	(0.119) **	0.014
Intermediate	0.516	(0.137) **	0.013
Lower Supervisory and Technical	0.551	(0.18) *	0.069
Semi-routine Occupation	0.543	(0.158) **	0.036
Routine Occupation	0.571	(0.191) *	0.094
Full-time Student	1.909	(0.686) *	0.072
Yearly income ( <i>ten thousands of £</i> )	1.082	(0.056) †	0.143

- The key attributes of the potential EV adopters are:
  - Higher education
  - Being a full-time student
  - Being married
  - Living in the south/middle of the UK
  - Lower age
  - Higher income
- The remaining consumer profile attributes have either a negative effect or are not significant.

# Results: Vehicle Attributes (Q. 2)

Thought of Buying an EV	Odds Ratio	Standard Error		P-value
Positive Effect on the Environment	1.163	(0.032)	***	0.000
Fully Electric	1.293	(0.08)	***	0.000
Style	0.932	(0.03)	**	0.03
Safety	0.951	(0.032)	†	0.132
Performance/Power	1.128	(0.071)	*	0.058
Purchase Cost	1.102	(0.04)	***	0.008
Recharging Cost	0.905	(0.05)	*	0.069
Lack of Knowledge	0.796	(0.045)	***	0.000
Range	1.085	(0.035)	**	0.012
Convenience of Recharging	0.941	(0.032)	*	0.075

- The potential early adopters of EVs in the UK give the greatest importance to:
  - Vehicle price
  - Performance
  - Range
  - Environmental impact

# Results: Key Barriers to UK EV Adoption (Q. 3)



Discouraged Potential Early Adopter	Coefficient	Standard Error	P-value
Vehicle Range	1.05	(0.04) †	0.117
Lack of Knowledge	0.81	(0.05) ***	0.001
Lack of Choice	0.96	(0.05)	0.408
Purchase Cost	1.07	(0.04) *	0.081
Recharging Costs	0.87	(0.05) **	0.015
Surveyed in 2015 (vs. 2014)	0.98	(0.15)	0.907
Freq. of Car Use	0.93	(0.05)	0.168
Southern UK Regions	1.22	(0.29)	0.398
Middle UK Regions	1.27	(0.32)	0.332
Northern UK Regions	0.76	(0.2)	0.303
Accommodation Owned	1.32	(0.26)	0.159
Household Size	0.99	(0.08)	0.866
Male	1.17	(0.19)	0.341
Age (years)	0.99	(0.007)	0.294
Married	1.14	(0.21)	0.479
No. of Vehicles	0.88	(0.1)	0.262
Higher Education	2.39	(0.74) ***	0.005
A Levels Equivalent	1.78	(0.61) *	0.09
Below A Levels	1.46	(0.48)	0.255
Other/Foreign Qualification	1.78	(0.63) †	0.103
Health (Likert scale)	0.83	(0.08) *	0.065
Long-run Illness/Disability	1.04	(0.2)	0.849
Routine/Semi-routine Jobs	0.63	(0.17) *	0.081
Small Employers	1.55	(0.42) †	0.105
Full-time Student	2.23	(0.84) **	0.033
Yearly income (ten thousands of £)	1.05	(0.06) †	0.367

- The key barriers identified are:
  - High purchase cost
  - Low maximum range
- Lack of knowledge about EV technology is found to have a significant negative effect.
  - Thus, lack of knowledge is a barrier to those that never considered an EV purchase, but not so for those who thought about buying an EV before.

- The results offer valuable information to manufacturers and the government for increasing adoption rates of EVs.
- The key characteristics of being a potential EV adopter are **youth** and **education**. Other characteristics include **being a student, living in the more southern parts of the UK, being married** and **income**.
- Important vehicle attributes include **purchase cost, performance** and **maximum range**.
- And finally, **high purchase cost** and **low maximum range** were found to be key barriers to adoption of EVs in the UK.

- Attributes of the potential EV consumers in the UK:
  - Policy makers should focus on younger, educated groups as a promising target for increasing adoption rates of EVs.
- Vehicle attributes affecting consumers' desire to buy EVs:
  - The focus of R&D should focus on improvements such as batteries, to lower purchase price and increase maximum range.
- Barriers to EV adoption for the potential EV consumers:
  - Lack of knowledge about EV technology was not found to be a barrier for potential EV adopters.
  - However, it may be a barrier for those that never thought of an EV purchase.
  - The government should thus target its education efforts on these individuals.