Emergence of electric mobility: a nested approach to vehicle choice modeling

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FÉDÉRALE DE LAUSANNE

Outline

- Introduction
- Data collection
  - Structure of survey
  - Choice situations
  - Target groups
  - Return rates
- Discrete choice model
  - Specification
  - Estimation results
- Conclusion & further work

Introduction

Current situation:

- **Electric vehicles (EV)** currently released on Swiss market
  ⇒ shares of car market affected

- Motivates **analysis of demand** for electric vehicles

Introduction

Aim:

- Analyze demand for EV for **private use**
  - Subcompact EV (Renault Zoé) 
  - Compact EV (Renault Fluence) 
- Identification of **target customers**
- Identification of **ideal pricing**:
  - Vehicle price
  - Possible governmental incentive
  - Costs of usage
  - Battery lease

Steps

Research steps:

- Design of a **stated preference (SP)** survey to analyze demand, in collaboration with Renault Suisse S.A.
- Calibration of a **discrete choice model (DCM)**
- Forecasting and sensitivity analysis (future works)

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Focus of this talk

- Design of a **stated preference (SP)** survey to analyze demand, in collaboration with Renault Suisse S.A.
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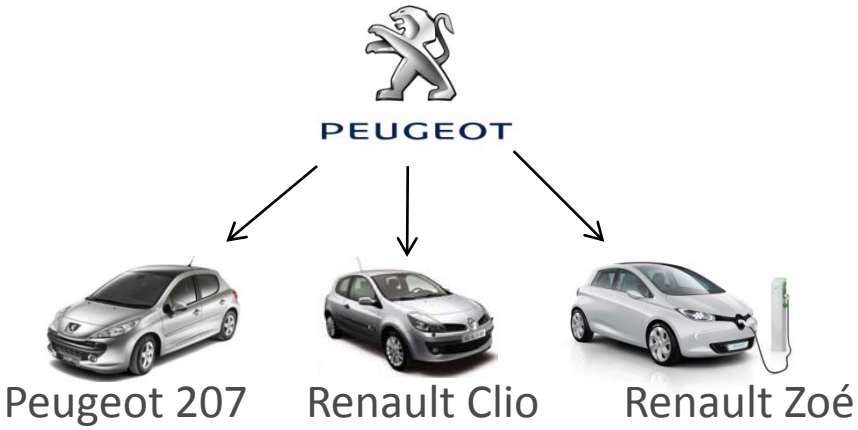
Data collection

Stated preference survey:

Hypothetical choices between

- Current vehicle of respondent
- (Possible) analogous petrol-driven model by Renault
- Analogous model in Renault electric product line



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Structure of the survey

Stated preference survey:

2 phases:

- **Phase I:**
  - Characteristics of respondent's car(s)
  - Socio-economic information
  - Mobility habits
- **Phase II:**
  - Opinions on topics related to EV
  - Choice situations

Structure of the survey

Stated preference survey:

2 phases:

- **Phase I:**
  - Characteristics of respondent's car(s) → **Creation of choice situations**
  - Socio-economic information
  - Mobility habits
- **Phase II:**
  - Opinions on topics related to EV
  - Choice situations

Structure of the survey

Stated preference survey:

2 phases:

- **Phase I:**
  - Characteristics of respondent's car(s)
  - Socio-economic information → **Segmentation, identification of potential users**
  - Mobility habits

- **Phase II:**
  - Opinions on topics related to EV
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Characterization of mobility of potential users:

- Total distance performed on each weekday
- Total distance performed in the weekend
- Average duration of weekday trips
- Number of cars in the household, etc.

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  - Opinions on topics related to EV →
  - Choice situations

Evaluation of effect of attitudes on choice:

- Environmental concern
- Attitude towards new technologies
- Perception of reliability of EV
- Importance of design
- Perception of leasing

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- **Phase I:**
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- **Phase II:**
  - Opinions on topics related to EV
  - Choice situations → **Core of SP survey**

Choice situations

Fractional factorial design

Aim: evaluate effect of prices on choice

Purchase price

Governmental incentive

Costs of fuel/electricity

Battery lease

Characteristics	Your vehicle	Renault vehicle with combustion engine	Renault electric vehicle
Make	Audi	Renault	Renault
Model	A4	Laguna	Fluence
Fuel	Petrol	Petrol	Electricity
Purchase price (in CHF)	42′400	37′200	56′880
Incentive (in CHF)	0	0	−1′000
Total purchase price (in CHF)	42′400	37′200	55′880
OR: Monthly leasing price (in CHF)	477	399	693
Maintenance costs (in CHF for 30′000 km)	850	850	425
Cost in fuel/electricity for 100 km (in CHF)	11.70	13.55	3.55
Battery lease (in CHF per month)	0	0	125
	☐	☐	☐

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Pricing design

Effect of prices on choice

EV variable	Level 1	Level 2	Level 3	Level 4
Purchase price	(P_{petrol}+ 5'000) * 0.8	(P_{petrol} + 5'000) * 1	(P_{petrol} + 5'000) * 1.2	-
Governmental incentive	- 0 CHF	- 500 CHF	- 1'000 CHF	- 5'000 CHF
Cost of fuel/electricity for 100 km	1.70 CHF	3.55 CHF	5.40 CHF	-
Battery lease	85 CHF	105 CHF	125 CHF	-

Target groups

Stated preference survey:

- **Sampling protocol** → representativity from:
  - 3 language regions of Switzerland (German, French, Italian)
  - Gender
  - Age category (18-35 years, 36-55 years, 56-74 years)
- **Target groups**:
  - Recent buyers
  - Prospective buyers
  - Renault customers

  Sampling protocol
  - Pre-orders
  - EV-fans

  All available

Return rates

Group name	Sent	Phase I		Phase II		Phase I vs phase II
		Number	Rate	Number	Rate	Rate
Recent buyers	3006	150	10.0%	141	9.4%	94.0%
Prospective buyers		151		141		93.4%
Renault customers	1000	145	14.5%	120	12.0%	82.8%
Pre-orders	42	23	54.8%	19	45.2%	82.6%
EV-fans	656	197	30.0%	172	26.2%	87.3%
Total	4704	666	14.2%	593	12.6%	89.0%

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High response rate, especially for pre-orders and EV-fans.

Model calibration

To analyse effect of prices on choice: **discrete choice model**

Assumption → underlying **nested** structures:

- Owned vs not owned
- Electric vs petrol

Development of different discrete choice models:

- **Logit** model with multiple alternatives
- **Nested logit** model
- **Cross-nested logit** models

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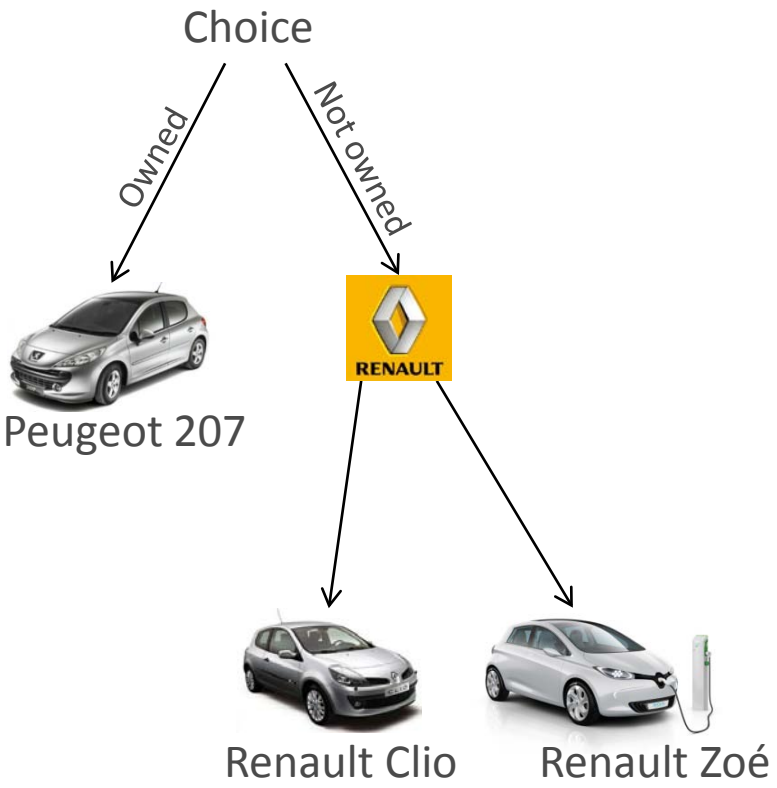
Model with best fit

Model calibration

Nested logit model:

$$P_n(i|C_n) = P_n(i|m, C_n)P_n(m|C_n)$$

$$P_n(i|C_n) = \frac{e^{\mu_m V_{in}}}{\sum_{j \in C_{mn}}} \frac{\left(\sum_{l \in C_{mn}} e^{\mu_m V_{ln}}\right)^{\frac{\mu}{\mu_m}}}{\sum_p \left(\sum_{l \in C_{pn}} e^{\mu_p V_{ln}}\right)^{\frac{\mu}{\mu_p}}}$$



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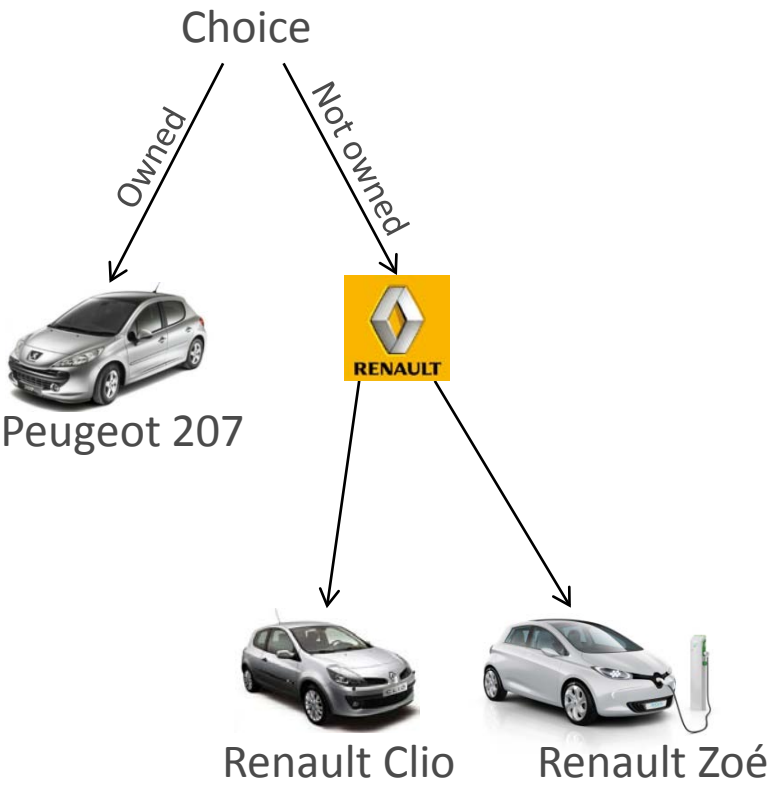
Deterministic utility → to be specified



Model calibration

Specification of the deterministic utility V_{in}

Utilities	Own car	Renault car	Electric car
ASC_{own}	1	-	-
ASC_{Renault}	-	1	-
$\beta_{\text{price}_{\text{own}}}$	$\text{price}_{\text{own}}$	-	-
$\beta_{\text{price}_{\text{Renault}}}$	-	$\text{price}_{\text{Renault}}$	-
$\beta_{\text{price}_{\text{elec}}}$	-	-	$\text{price}_{\text{elec}}$
β_{UseCost}	$\text{UseCost}_{\text{own}}$	$\text{UseCost}_{\text{Renault}}$	-
$\beta_{\text{UseCost}_{\text{elec}}}$	-	-	$\text{UseCost}_{\text{elec}}$
$\beta_{\text{BatteryHigh}}$	-	-	BatteryHigh
$\beta_{\text{IncentiveHigh}}$	-	-	IncentiveHigh
$\beta_{\text{SocioEco1}}$	SocioEco1	SocioEco1	-
$\beta_{\text{SocioEco2}}$	SocioEco2	SocioEco2	-
$\beta_{\text{SocioEco3}}$	SocioEco3	SocioEco3	-
$\beta_{\text{SocioEco4}}$	-	SocioEco4	SocioEco4
$\beta_{\text{SocioEco5}}$	-	SocioEco5	SocioEco5

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$\beta_{\text{BatteryHigh}}$	-	-	BatteryHigh
$\beta_{\text{IncentiveHigh}}$	-	-	IncentiveHigh
$\beta_{\text{SocioEco1}}$	SocioEco1	SocioEco1	-
$\beta_{\text{SocioEco2}}$	SocioEco2	SocioEco2	-
$\beta_{\text{SocioEco3}}$	SocioEco3	SocioEco3	-
$\beta_{\text{SocioEco4}}$	-	SocioEco4	SocioEco4
$\beta_{\text{SocioEco5}}$	-	SocioEco5	SocioEco5

- Purchase price, alternative specific

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$\beta_{\text{BatteryHigh}}$	-	-	BatteryHigh
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$\beta_{\text{SocioEco1}}$	SocioEco1	SocioEco1	-
$\beta_{\text{SocioEco2}}$	SocioEco2	SocioEco2	-
$\beta_{\text{SocioEco3}}$	SocioEco3	SocioEco3	-
$\beta_{\text{SocioEco4}}$	-	SocioEco4	SocioEco4
$\beta_{\text{SocioEco5}}$	-	SocioEco5	SocioEco5

- Purchase price, alternative specific
- Refueling/recharging costs, specific to fuel type

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- Purchase price, alternative specific
- Refueling/recharging costs, specific to fuel type
- Other design variables: battery lease and incentive

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- Purchase price, alternative specific
- Refueling/recharging costs, specific to fuel type
- Other design variables: battery lease and incentive
- Socio-economic information

Estimation results

Model estimation:

- **Nested logit** model estimated by **maximum likelihood**
- Extended version of software **BIOGEME** (Bierlaire and Fetiarison, 2009)
- All parameters significant at 95% level of confidence, except battery lease at 90%

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Estimation results

	Nested logit model		Base model	
Variable	Estimate	t-test	Estimate	t-test
ASC_{own}	0.05	0.19	0.37	1.51
$\text{ASC}_{\text{Renault}}$	-0.35	-1.47	-0.72	-2.14
$\text{Price}_{\text{own}}$	-0.03	-2.32	-0.03	-2.11
$\text{Price}_{\text{Renault}}$	-0.30	-5.70	-0.26	-3.66
$\text{Price}_{\text{elec}}$	-0.40	-9.84	-0.45	-10.73
UseCost	-0.05	-2.33	-0.08	-3.59
$\text{UseCost}_{\text{elec}}$	-0.18	-2.50	-0.21	-2.44
BatteryHigh	-0.12	-1.63	-0.18	-2.07
IncentiveHigh	0.57	6.69	0.65	7.18
SocioEco1	-0.39	-4.40	-0.49	-5.28
SocioEco2	-0.22	-2.98	-0.29	-3.53
SocioEco3	-0.15	-3.25	-0.20	-3.96
SocioEco4	0.25	3.10	0.25	3.07
SocioEco5	-0.23	-2.47	-0.22	-2.37
μ_{Renault}	1.69	6.20	-	-
Log-likelihood		-2237.64		-2242.49

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- Utility of any vehicle ↘ as purchase price ↗
Effect most important for EV

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- Utility of any vehicle ↘ as purchase price ↗
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- Utility of any vehicle ↘ as refueling/recharging costs ↗
  For EV, only significant effect for highest level of charging cost

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- Significant effect of high levels of battery lease (-) and incentive (+) on choice of EV

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- Utility of any vehicle ↘ as refueling/recharging costs ↗
  For EV, only significant effect for highest level of charging cost
- Significant effect of high levels of battery lease (-) and incentive (+) on choice of EV
- Identification of socio-economic segments

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Log-likelihood		-2237.64		-2242.49

- Nest parameter for vehicles not owned by respondent significantly different from 1.

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Estimation results

Variable	Nested logit model Estimate	*t*-test	Base model Estimate	*t*-test
ASC_{own}	0.05	0.19	0.37	1.51
$ASC_{Renault}$	-0.35	-1.47	-0.72	-2.14
$Price_{own}$	-0.03	-2.32	-0.03	-2.11
$Price_{Renault}$	-0.30	-5.70	-0.26	-3.66
$Price_{elec}$	-0.40	-9.84	-0.45	-10.73
UseCost	-0.05	-2.33	-0.08	-3.59
$UseCost_{elec}$	-0.18	-2.50	-0.21	-2.44
BatteryHigh	-0.12	-1.63	-0.18	-2.07
IncentiveHigh	0.57	6.69	0.65	7.18
SocioEco1	-0.39	-4.40	-0.49	-5.28
SocioEco2	-0.22	-2.98	-0.29	-3.53
SocioEco3	-0.15	-3.25	-0.20	-3.96
SocioEco4	0.25	3.10	0.25	3.07
SocioEco5	-0.23	-2.47	-0.22	-2.37
$\mu_{Renault}$	1.69	6.20	-	-
Log-likelihood		-2237.64		-2242.49

- Nest parameter for vehicles not owned by respondent significantly different from 1.
- Likelihood ratio test shows significant improvement of fit over logit model.

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Evidence for existence of nested structure.

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Conclusion

- Application of **DCM**:
  - **Price** of each vehicle perceived differently
  - **Battery lease**, **incentive** and **recharging costs** have significant impact on choice of EV
  - **Segments** potentially interested by EV identified

- Calibration of **nested logit** model:
  - Common characteristics between **alternatives not owned** by respondents can be captured
  - Significantly **improved fit** over logit model

Further work

Modeling: introduction of other aspects into model:

- **Attitudes** → Perception of EV as an ecological solution
- **Mobility habits** → target customers for EV
  - Households with ≥ 2 cars
  - Individuals performing short daily travel durations

Forecasting:

- Evaluation of **potential market shares** for EV
- Sensitivity analysis

Thanks!

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