Integrating Latent Concepts in a Demand Model for Electric Vehicles

Aurélie Glerum, TRANSP-OR, EPFL
Michaël Thémans, TRACE, EPFL
Michel Bierlaire, TRANSP-OR EPFL

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Outline

- Introduction & motivation
- Data collection
- Methodology
- Estimation results
- Conclusion
- Further work

Introduction & motivation

Current situation:

- Search for ecological alternatives to fossil fuels:
  - Alternative fuel vehicles (LPG, CNG, etc.)
  - Electric vehicles (EV) being released

Collaborative project EPFL-Renault:

- Renault launches Zero Emission (Z.E.) product line in 2011-2012

Introduction & motivation

The **electric vehicle**

- No CO_2 emissions
- No noise
- 185 km range
- 8h to charge battery completely
- Restricted charging locations

Variables that can influence **people's purchase choices.**

Introduction & motivation

Objective of research project:

- Analysis and prediction of **demand for electric vehicles** for **private use**

Research steps:

1. Design of stated preference survey: **hypothetical choice situations**
   - Classical vehicles (petrol, diesel, etc.)
   - Electric vehicles (from Renault Z.E. product line)

Zoé 

Fluence Z.E. 

2. Application of **discrete choice methodology**
3. **Forecasting** of market shares

Introduction & motivation

Objective of research project:

- Analysis and prediction of **demand for electric vehicles** for **private use**

Focus of this talk

Research steps:

1. Design of stated preference survey: **hypothetical choice situations**
   - Classical vehicles (petrol, diesel, etc.)
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2. Application of **discrete choice methodology**
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Introduction & motivation

Research issues raised:

- **Design of survey:** choice situations close to reality

- **Modeling:** develop discrete choice models to evaluate **demand for EV**:
  - Identification of **target customers**
  - Identification of **ideal pricing** of EV: i.e. analyze impact on choice of:
    - Vehicle price
    - Costs of usage
    - Battery lease
    - Potential governmental incentive
  - Assessment of the impact of **attitudes** and **perceptions** on choice

- **Forecasting:** predict in realistic way the **market shares of EV** and classical vehicles among the **target population of new buyers** in Switzerland

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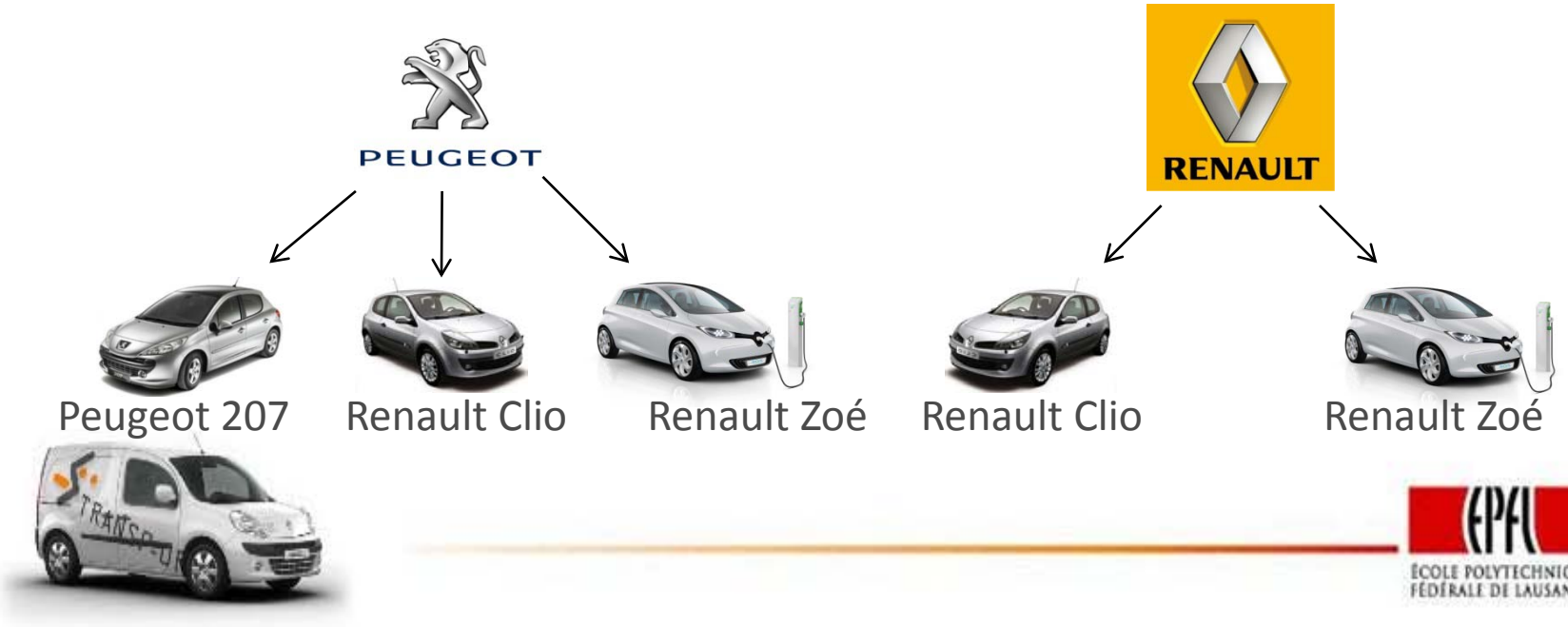
Data collection: type of survey

Type of survey: **stated preference (SP)** survey

- **Within same car segment**: **hypothetical** choices between
  - Own car
  - Renault – gasoline
  - Renault – electric



Data collection: sample

5 types of respondents sampled in Switzerland:

- Recent buyers
- Prospective buyers
- Renault customers
- Pre-orders
- Newsletter

Sampling protocol → representativity from:

- 3 language regions of Switzerland (German, French, Italian)
- Gender
- Age category (18-35 years, 36-55 years, 56-74 years)

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Sampling protocol

All available

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Data collection: structure of 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
  - Perceptions of four categories of EV
  - Choice situations

Data collection: structure of 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
  - Perceptions of four categories of EV
  - Choice situations

Data collection: structure of survey

2 phases:

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

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.

Data collection: structure of survey

2 phases:

- **Phase I:**
  - Characteristics of respondent's car(s)
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  - Mobility habits
- **Phase II:**
  - Opinions on topics related to EV →
  - Perceptions of four categories of 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

Data collection: structure of survey

2 phases:

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

Evaluation of effect of perceptions on choice:

- Vehicles with combustion engine
- Hybrid vehicles
- Electric vehicles
- Renault vehicles

Data collection: structure of survey

2 phases:

- **Phase I:**
  - Characteristics of respondent's car(s)
  - Socio-economic information
  - Mobility habits

- **Phase II:**
  - Opinions on topics related to EV
  - Perceptions of four categories of EV
  - Choice situations → **• Core of SP survey**

• 5 choice experiments per individual

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Data collection: structure of survey

An example of choice experiment

Reported by respondent

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
	☐	☐	☐

Data collection: structure of survey

An example of choice experiment

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Deduced from segment of owned car

Data collection: structure of survey

An example of choice experiment

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Obtained from data base of cars currently sold on market

Data collection: structure of survey

An example of choice experiment

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Fixed attributes

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Data collection: structure of survey

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Design variables

Data collection: structure of survey

Design variables

EV variable	Level 1	Level 2	Level 3	Level 4
Purchase price	(P_{own} + 5'000) * 0.8	(P_{own}+ 5'000) * 1	(P_{own} + 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	-

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Methodology: experimental design

Experimental design:

- Fractional factorial design
- Four-factor interactions confounded ⟶ resolution V
- Blocking with respect to 4 target groups:
  1. Recent buyers
  2. Prospective buyers
  3. Renault customers
  4. Pre-orders
     Newsletter

Methodology: experimental design

Sampling procedure:

1. Selection of **sequences of levels** relative to respondent's **sample group**
2. Sampling **with replacement between individuals**
3. Sampling **without replacement** for choice situations of **each individual**

Sampling weights:

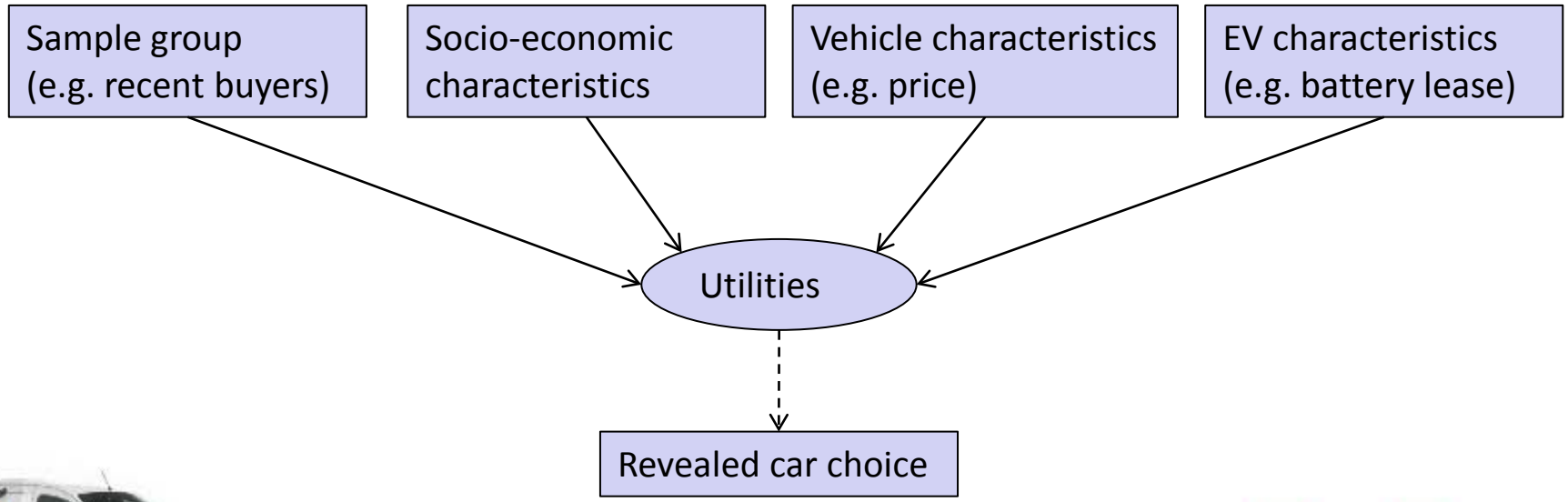
- Correct for **oversampling** of some levels
- Weights computed with **iterative proportional fitting (IPF)**

	Incentive	Price	Fuel cost of 100 km	Battery lease
1	0	0.80	1.70	85
2	0	1.00	3.55	125
3	0	1.00	5.40	105
4	0	1.20	3.55	105
5	-500	0.80	1.70	125
6	-500	1.00	3.55	85
7	-500	1.00	5.40	105
8	-500	1.20	3.55	105
9	-1000	0.80	3.55	105
10	-1000	1.00	5.40	105
11	-1000	1.00	3.55	85
12	-1000	1.20	1.70	125
13	-5000	0.80	3.55	105
14	-5000	1.00	5.40	105
15	-5000	1.00	3.55	125
16	-5000	1.20	1.70	85

Methodology: discrete choice model

- Achieve modeling and forecasting goals
  ⟶ use of discrete choice methodology

- Logit model with multiple alternatives



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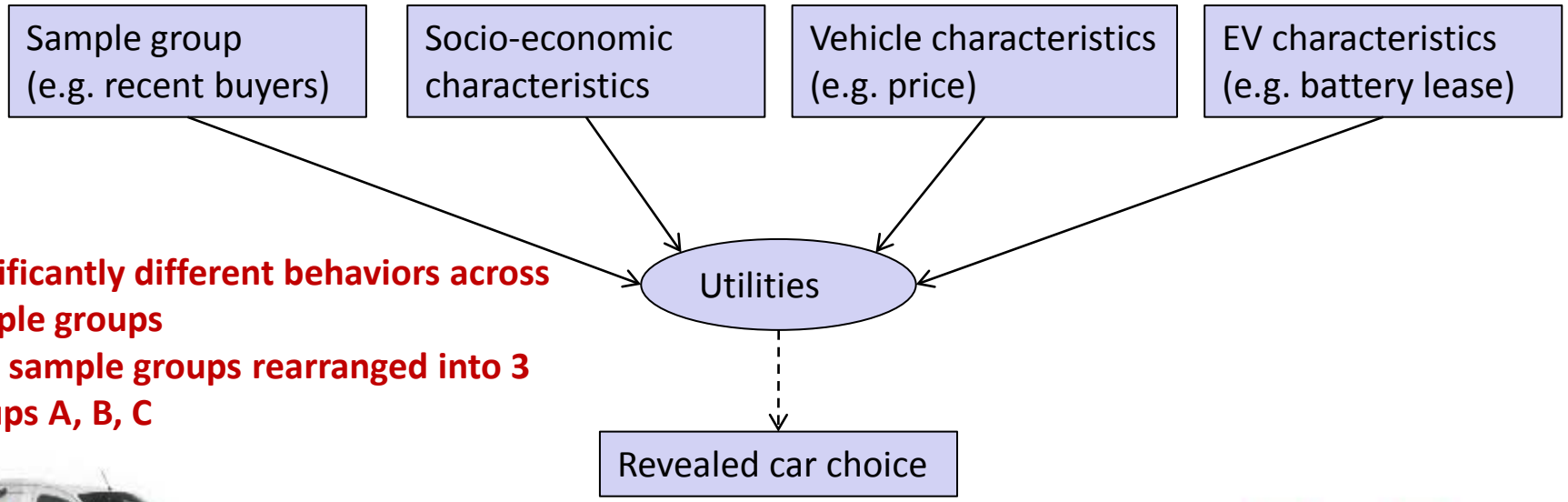

Significantly different behaviors across sample groups
➔ 5 sample groups rearranged into 3 groups A, B, C

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Estimation results 1

	Gasoline – competitors (GC)		Gasoline – Renault (GR)		Electric – Renault (EV)	
	Estimate	t-test	Estimate	t-test	Estimate	t-test
ASC GASOLINE COMPETITORS	-1.16	-2.94				
ASC GASOLINE RENAULT			-1.39	-3.57		
PRICE GASOLINE COMPETITORS	-0.0225	-1.31				
PRICE GASOLINE RENAULT A,C			-0.225	-4.03		
PRICE GASOLINE RENAULT B			-0.645	-4.57		
PRICE ELECTRIC RENAULT A					-0.347	-5.63
PRICE ELECTRIC RENAULT B					-0.922	-6.24
PRICE ELECTRIC RENAULT C					-0.545	-7.66
COST OF REFUELING (SMALL CONSUMPTION)	-0.0384	-1.57	-0.0384	-1.57		
COST OF RECHARGING BATTERY (HIGH)					-0.424	-3.69
COST OF RECHARGING BATTERY (MEDIUM)					-0.13	-1.18
BATTERY LEASE (HIGH)					-0.206	-1.79
BATTERY LEASE (MEDIUM)					-0.0626	-0.58
INCENTIVE (HIGH)					0.721	5.73
INCENTIVE (MEDIUM)					0.0803	0.61
INCENTIVE (LOW)					0.0179	0.14

Estimation results 1

Price affects negatively utility of 3 vehicles.

Average impact
1) highest for EV
2) second highest for GR
3) lowest for GC

	Gasoline – competitors (GC)		Gasoline – Renault (GR)		Electric – Renault (EV)	
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Estimation results 1

Price affects negatively utility of 3 vehicles.

Average impact
1) highest for EV
2) second highest for GR
3) lowest for GC

Effect of price of GR and EV more important for **group B**.

	Gasoline – competitors (GC)		**Gasoline – Renault (GR)**		**Electric – Renault (EV)**	
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Estimation results 1

Price affects negatively utility of 3 vehicles.

Average impact
1) highest for EV
2) second highest for GR
3) lowest for GC

Effect of price of GR and EV more important for **group B**.

Effect of price of EV least important for **groups C**.

	Gasoline – competitors (GC)		**Gasoline – Renault (GR)**		**Electric – Renault (EV)**	
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Estimation results 1

Cost of refueling:

negative effect on choice of gasoline cars with
use cost < 15 CHF / 100 km

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Estimation results 1

Design variables:

1) Negative effect of high charging costs (5.40 CHF)

2) Negative effect of high battery lease (125 CHF)

3) Positive effect of high incentive (5'000 CHF)

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Estimation results 2

	Gasoline – competitors (GC)		Gasoline – Renault (GR)		Electric – Renault (EV)	
	Estimate	t-test	Estimate	t-test	Estimate	t-test
SAMPLE GROUP A COMP.	1.89	5.18				
SAMPLE GROUP B COMP.	-1.24	-1.67				
SAMPLE GROUP A REN.			0.922	2.57		
SAMPLE GROUP B REN.			2.31	4.59		
USE PT GAS. A,C COMP.	-0.389	-3.03				
USE PT GAS. B COMP.	-1.59	-2.28				
USE PT GAS. REN.			-0.682	-5.44		
FAMILY STATUS GAS. COMP.	-0.242	-2.15				
FAMILY STATUS GAS. REN.			0.0523	0.5		
INCOME GAS. COMP.	-0.273	-2.41				
INCOME GAS. REN.			-0.279	-2.66		
CARS HOUSEHOLD GAS. COMP.	-0.166	-2.26				
CARS HOUSEHOLD GAS. A,C REN.			-0.161	-2.21		
CARS HOUSEHOLD GAS. B REN.			-0.668	-5.56		

Estimation results 2

Socio-economic characteristics have meaningful interpretation.

Related to:

- Sample group
- Usage of public transport
- Family status
- Income
- Cars in the household

Differences across sample groups captured

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Conclusion

Model demand for electric vehicles:

Survey:

- Realistic choice context: adapted to respondent

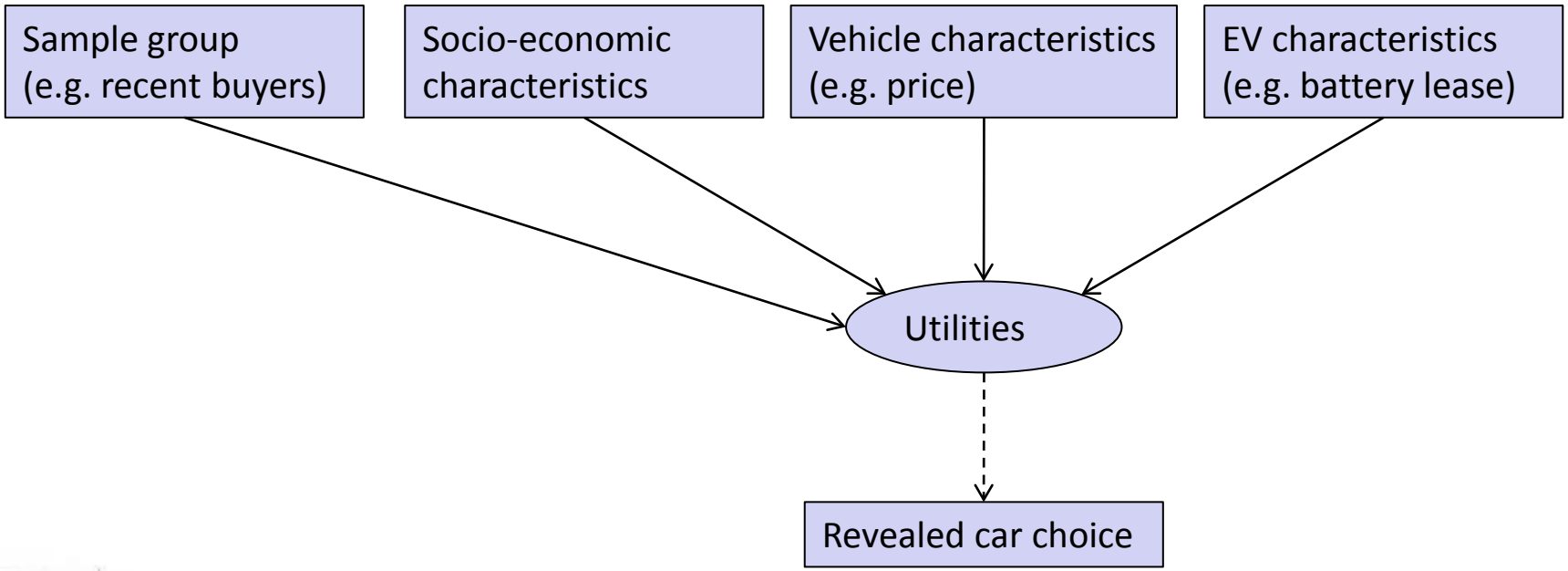
Model:

- Estimation results with meaningful interpretation
- Assess impact of price characteristics
- Identify target customers

Further work: modeling

Improve **specification**:

Capture effect on choice of unobserved variables (**attitudes**, **perceptions**)



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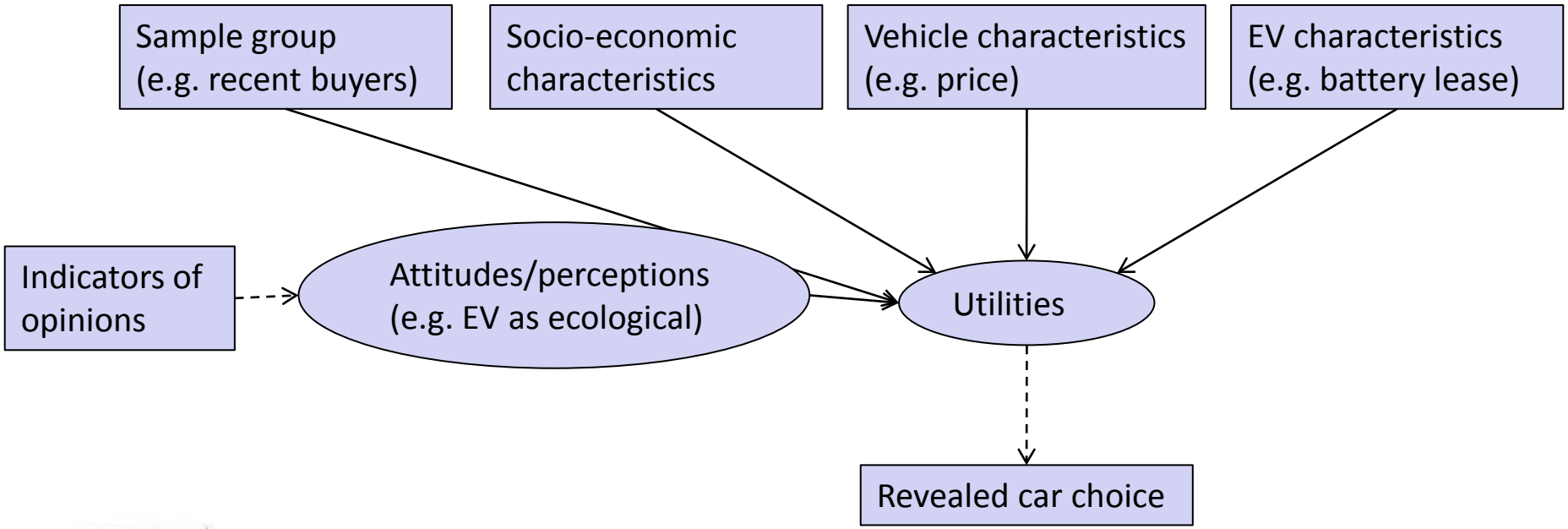
Capture effect on choice of unobserved variables (**attitudes**, **perceptions**)



Integrated choice and latent variable model (Walker, 2001)

Further work: forecasting

Model estimates ⟶ obtain **market shares**

Correction of market shares needed ⟶ make them realistic by correcting them with market data:

- Correction of **ASC** relative to gasoline alternatives:
  - Socio-demographic characteristics (age, gender, language)
  - Sample group (recent & prospective buyers, Renault customers, pre-orders, newsletter)
- Correction for **missing alternative** 'gasoline-competitors' for owners of a Renault car
- Correction for missing alternative '**None of the cars**'

Thanks!

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