Mathematical modeling of choice behavior: from theory to practice

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Outline

1 Motivation
   - Literature review
   - Need to model behavior
   - Applications
   - Importance

2 Some theory
   - Decision rule

3 The random utility model
4 Questioning rationality
5 Choice data
5 Case studies
   - Market shares of electrical vehicles
   - Value of time
   - Path to purchase

6 Conclusion
Psychohistory

Branch of mathematics which deals with the reactions of human conglomerates to fixed social and economic stimuli. The necessary size of such a conglomerate may be determined by Seldon’s First Theorem.

*Encyclopedia Galactica, 116th Edition (1020 F.E.)*

*Encyclopedia Galactica Publishing Co., Terminus*

Motivation: shorten the period of barbarism after the Fall of the Galactic Empire
Albus Dumbledore
It is our choices that show what we truly are, far more than our abilities

Jean-Paul Sartre
We are our choices

Ken Levine
- We all make choices, but in the end our choices make us.
- In the end what separates a man from a slave? Money? Power? No, a man chooses… a slave obeys.
Motivation

Human dimension in
- engineering
- business
- marketing
- planning
- policy making
Theories and methods

Need for
- behavioral theories
- quantitative methods
- operational mathematical models
Economic approach

Concept of demand
- marketing
- transportation
- energy
- finance
Transportation

- Supply = infrastructure
- Demand = behavior, choices
- Congestion = mismatch
Transportation

- Usually in operations research:
  - optimization of the supply
  - for a given (fixed) demand
Aggregate demand

- Homogeneous population
- Identical behavior
- Price \((P)\) and quantity \((Q)\)
- Demand functions: \(P = f(Q)\)
- Inverse demand: \(Q = f^{-1}(P)\)
Motivation

Need to model behavior

Disaggregate demand

- Heterogeneous population
- Different behaviors
- Many variables:
  - Attributes: price, travel time, reliability, frequency, etc.
  - Characteristics: age, income, education, etc.
- Complex demand/inverse demand functions.
Motivation

Need to model behavior

Choices

Concept of choice

- Marketing: brand, product
- Transport: mode, destination
- Energy: type, usage
- Finance: buy/sell, product
Applications

Willingness to pay for travel time savings

- Swiss Federal Road Office
- Compute the Swiss value of time
Applications

Route choice

- How do travelers select an itinerary?
- Impact of information and guidance
- Data: Nokia
Applications

Market share of electrical vehicles

- Renault Suisse
- Forecasting of market shares
Applications

Dynamics of vehicle ownership

- PSA Peugeot Citroën
- Vehicle transactions model
- Changes in households vehicle ownership
Applications

Path to purchase: the case of ice creams

- Nestlé Research Center
- Impact of the design of the poster
- on the choice of ice cream
Applications

Automatic analysis of facial expressions

- Images and videos
- Signal Processing Lab
- Classification algorithm
Importance

Daniel L. McFadden

- Laureate of *The Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel 2000*
- Owns a farm and vineyard in Napa Valley
- “Farm work clears the mind, and the vineyard is a great place to prove theorems”
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6 Conclusion
Homo economicus
Decision rule

Homo economicus
Rational and narrowly self-interested economic actor who is optimizing her outcome

Utility

\[ U_n : C_n \rightarrow \mathbb{R} : a \mapsto U_n(a) \]

- captures the attractiveness of an alternative
- measure that the decision maker wants to optimize

Behavioral assumption
- the decision maker associates a utility with each alternative
- the decision maker is a perfect optimizer
- the alternative with the highest utility is chosen
Simple example: mode choice

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Travel time ($t$)</th>
<th>Travel cost ($c$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car (1)</td>
<td>$t_1$</td>
<td>$c_1$</td>
</tr>
<tr>
<td>Bus (2)</td>
<td>$t_2$</td>
<td>$c_2$</td>
</tr>
</tbody>
</table>
Simple example: mode choice

Utility functions

\[ U_1 = -\beta_t t_1 - \beta_c c_1, \]
\[ U_2 = -\beta_t t_2 - \beta_c c_2, \]

where \( \beta_t > 0 \) and \( \beta_c > 0 \) are parameters.

Equivalent specification

\[ U_1 = -(\beta_t / \beta_c) t_1 - c_1 = -\beta t_1 - c_1 \]
\[ U_2 = -(\beta_t / \beta_c) t_2 - c_2 = -\beta t_2 - c_2 \]

where \( \beta > 0 \) is a parameter.

Choice

- Alternative 1 is chosen if \( U_1 \geq U_2 \).
- Ties are ignored.
Some theory  Decision rule

Simple example: mode choice

Choice

Alternative 1 is chosen if

\[-\beta t_1 - c_1 \geq -\beta t_2 - c_2\]

or

\[-\beta(t_1 - t_2) \geq c_1 - c_2\]

Alternative 2 is chosen if

\[-\beta t_1 - c_1 \leq -\beta t_2 - c_2\]

or

\[-\beta(t_1 - t_2) \leq c_1 - c_2\]

Dominated alternative

- If \(c_2 > c_1\) and \(t_2 > t_1\), \(U_1 > U_2\) for any \(\beta > 0\)
- If \(c_1 > c_2\) and \(t_1 > t_2\), \(U_2 > U_1\) for any \(\beta > 0\)
Simple example: mode choice

Trade-off

- Assume $c_2 > c_1$ and $t_1 > t_2$.
- Is the traveler willing to pay the extra cost $c_2 - c_1$ to save the extra time $t_1 - t_2$?
- Alternative 2 is chosen if

$$-\beta (t_1 - t_2) \leq c_1 - c_2$$

or

$$\beta \geq \frac{c_2 - c_1}{t_1 - t_2}$$

- $\beta$ is called the \textit{willingness to pay or value of time}
Simple example: mode choice

\[ c_1 + \beta t_1 = c_2 + \beta t_2 \]

Alt. 1 is chosen, Alt. 2 is chosen.

Alt. 2 is preferred, Alt. 1 is preferred.

Alt. 1 is dominant, Alt. 2 is dominant.

Alt. 1 is preferred, Alt. 2 is preferred.

M. Bierlaire (EPFL)  Modeling behavior
Random utility model

Random utility

\[ U_{in} = V_{in} + \varepsilon_{in}. \]

The logit model

\[ P(i|C_n) = \frac{e^{V_{in}}}{\sum_{j \in C_n} e^{V_{jn}}} \]
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Homo economicus?
Motivation

Rationality?

- Standard random utility assumptions are often violated.
- Factors such as attitudes, perceptions, knowledge are not reflected.
Example: pain lovers


- Short trial: immerse one hand in water at $14^\circ$ for 60 sec.
- Long trial: immerse the other hand at $14^\circ$ for 60 sec, then keep the hand in the water 30 sec. longer as the temperature of the water is gradually raised to $15^\circ$.
- Outcome: most people prefer the long trial.
- Explanation:
  - duration plays a small role
  - the peak and the final moments matter
Example: *The Economist*

Subscription to *The Economist*

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Web only</td>
<td>@ $59</td>
</tr>
<tr>
<td>Print only</td>
<td>@ $125</td>
</tr>
<tr>
<td>Print and web</td>
<td>@ $125</td>
</tr>
</tbody>
</table>
Example: *The Economist*

Subscription to *The Economist*

<table>
<thead>
<tr>
<th></th>
<th>Experiment 1</th>
<th>Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web only</td>
<td>@ $59</td>
<td>Web only @ $59</td>
</tr>
<tr>
<td>Print only</td>
<td>@ $125</td>
<td></td>
</tr>
<tr>
<td>Print and web</td>
<td>@ $125</td>
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</tr>
</tbody>
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Example: *The Economist*

**Subscription to The Economist**

<table>
<thead>
<tr>
<th></th>
<th>Experiment 1</th>
<th>Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16 Web only @ $59</td>
<td>68 Web only @ $59</td>
</tr>
<tr>
<td></td>
<td>0 Print only @ $125</td>
<td></td>
</tr>
<tr>
<td></td>
<td>84 Print and web @ $125</td>
<td>32 Print and web @ $125</td>
</tr>
</tbody>
</table>

Source: Ariely (2008)

- Dominated alternative
- According to utility maximization, should not affect the choice
- But it affects the perception, which affects the choice.
Example: good or bad wine?

Choose a bottle of wine...

<table>
<thead>
<tr>
<th></th>
<th>Experiment 1</th>
<th>Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>McFadden red at $10</td>
<td>McFadden red at $10</td>
</tr>
<tr>
<td>2</td>
<td>Nappa red at $12</td>
<td>Nappa red at $12</td>
</tr>
<tr>
<td>3</td>
<td>McFadden special reserve pinot noir at $60</td>
<td>Most would choose 2</td>
</tr>
<tr>
<td></td>
<td>Most would choose 2</td>
<td>Most would choose 1</td>
</tr>
</tbody>
</table>

Context plays a role on perceptions
Example: live and let die

Population of 600 is threatened by a disease. Two alternative treatments to combat the disease have been proposed.

<table>
<thead>
<tr>
<th>Experiment 1</th>
<th>Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td># resp. = 152</td>
<td># resp. = 155</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment A:</th>
<th>Treatment C:</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 people saved</td>
<td>400 people die</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment B:</th>
<th>Treatment D:</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 people saved with prob. 1/3</td>
<td>0 people die with prob. 1/3</td>
</tr>
<tr>
<td>0 people saved with prob. 2/3</td>
<td>600 people die with prob. 2/3</td>
</tr>
</tbody>
</table>
Example: live and let die

Population of 600 is threatened by a disease. Two alternative treatments to combat the disease have been proposed.

<table>
<thead>
<tr>
<th></th>
<th>Experiment 1</th>
<th>Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td># resp.</td>
<td>152</td>
<td>155</td>
</tr>
<tr>
<td>Treatment A:</td>
<td>72%</td>
<td>22%</td>
</tr>
<tr>
<td>200 people saved</td>
<td></td>
<td>400 people die</td>
</tr>
<tr>
<td>Treatment B:</td>
<td>28%</td>
<td></td>
</tr>
<tr>
<td>600 people saved with prob. 1/3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 people saved with prob. 2/3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment C:</td>
<td></td>
<td>22%</td>
</tr>
<tr>
<td>400 people die</td>
<td></td>
<td>400 people die</td>
</tr>
<tr>
<td>Treatment D:</td>
<td>78%</td>
<td></td>
</tr>
<tr>
<td>0 people die with prob. 1/3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>600 people die with prob. 2/3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Tversky & Kahneman (1986)
Example: to be free

Choice between a fine and a regular chocolate

<table>
<thead>
<tr>
<th></th>
<th>Experiment 1</th>
<th>Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lindt</td>
<td>$0.15</td>
<td>$0.14</td>
</tr>
<tr>
<td>Hershey</td>
<td>$0.01</td>
<td>$0.00</td>
</tr>
<tr>
<td>Lindt chosen</td>
<td>73%</td>
<td>31%</td>
</tr>
<tr>
<td>Hershey chosen</td>
<td>27%</td>
<td>69%</td>
</tr>
</tbody>
</table>

Operational models

Behavioral aspects
- Attitudes
- Habits
- Perceptions
- Social norms
- etc.

Modeling framework
- Random utility
- Latent variables

Data
- Choice data
- Psychometrics
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Choice data

**Revealed preferences**
- actual choice observed
- in real market situations
- Example: scanner data in supermarkets

**Stated preferences**
- hypothetical situations
- attributes defined by the analyst
Data

Questionnaires

- Data about the respondent
- Choice data
- Revealed preferences
- Stated preferences
Data: example of a questionnaire

### Situation de choix 4 de 5

Vous avez ici la description de votre véhicule actuel ainsi que celle de véhicules similaires, thermique et électrique, de la marque Renault. Compte tenu des caractéristiques de chacun de ceux-ci, laquelle des trois solutions choisiriez-vous, si vous deviez changer de voiture aujourd'hui ?

Les valeurs indicatives de leasing sont calculées sur la base d’un apport initial de 20%, d’un kilométrage annuel de 10'000 km et d’une durée de financement de 48 mois.

<table>
<thead>
<tr>
<th>Caractéristiques</th>
<th>Votre véhicule</th>
<th>Véhicule thermique Renault</th>
<th>Véhicule électrique Renault</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marque</td>
<td>SEAT</td>
<td>RENAULT</td>
<td>RENAULT</td>
</tr>
<tr>
<td>Modèle</td>
<td>LEON</td>
<td>MEGANE</td>
<td>FLUENCE</td>
</tr>
<tr>
<td>Carburant</td>
<td>Diesel</td>
<td>Diesel</td>
<td>Electricité</td>
</tr>
<tr>
<td>Prix d’achat (en CHF)</td>
<td>37510</td>
<td>42739</td>
<td>34008</td>
</tr>
<tr>
<td>Prime du gouvernement (en CHF)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Prix total à l’achat (en CHF)</td>
<td>37510</td>
<td>42739</td>
<td>34008</td>
</tr>
<tr>
<td>OU : Prix mensuel du leasing (en CHF)</td>
<td>402</td>
<td>435</td>
<td>404</td>
</tr>
<tr>
<td>Coûts d’entretien (en CHF par 30'000 km)</td>
<td>850</td>
<td>850</td>
<td>425</td>
</tr>
<tr>
<td>Coût en carburant/électricité par 100 km (en CHF)</td>
<td>9.65</td>
<td>10.8</td>
<td>3.55</td>
</tr>
<tr>
<td>Leasing de la batterie (en CHF par mois)</td>
<td>0</td>
<td>0</td>
<td>0.105</td>
</tr>
</tbody>
</table>
Data

Smartphones

- GSM, GPS
- Accelerometer
- WiFi
- Bluetooth
- Ambient sound
- And more...
Data

Scanner data
- Detailed purchase information
- Personalized
Data

Eye tracking
- Where do people look?
- Used in marketing research
- Used in driving safety research
- Relevant for pedestrian models
Data: eye tracking

Movie: Nestlé data collection
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   - Path to purchase

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Market shares of electrical vehicles

Forecasting the demand for electric vehicles: accounting for attitudes and perceptions, *Transportation Science* (accepted for publication on May 29, 2013)

**Objectives**

Demand analysis for two electrical vehicles: Zoe & Fluence (Renault)
Sample

Target groups

**Sampling from**
- Recent buyers
- Prospective buyers
- Renault customers

**Everybody from**
- Pre-orders
- Z. E. newsletter

Sampling protocol: representative for
- 3 language regions of Switzerland (German, French, Italian)
- Gender
- Age category (18–35, 36-55, 56–74)
Sample

High response rate - possibility to segment

<table>
<thead>
<tr>
<th>Group name</th>
<th>Sent</th>
<th>Phase I</th>
<th></th>
<th>Phase II</th>
<th></th>
<th>Phase I vs phase II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number</td>
<td>Rate</td>
<td>Number</td>
<td>Rate</td>
<td>Rate</td>
</tr>
<tr>
<td>Recent buyers</td>
<td>3006</td>
<td>150</td>
<td>10.0%</td>
<td>141</td>
<td>9.4%</td>
<td>94.0%</td>
</tr>
<tr>
<td>Prospective buyers</td>
<td>1000</td>
<td>151</td>
<td>14.5%</td>
<td>141</td>
<td>12.0%</td>
<td>93.4%</td>
</tr>
<tr>
<td>Renault customers</td>
<td>1000</td>
<td>145</td>
<td>14.5%</td>
<td>120</td>
<td>12.0%</td>
<td>82.8%</td>
</tr>
<tr>
<td>Pre-orders</td>
<td>42</td>
<td>23</td>
<td>54.8%</td>
<td>19</td>
<td>45.2%</td>
<td>82.6%</td>
</tr>
<tr>
<td>Z.E. newsletter</td>
<td>656</td>
<td>197</td>
<td>30.0%</td>
<td>172</td>
<td>26.2%</td>
<td>87.3%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>4704</td>
<td>666</td>
<td>14.2%</td>
<td>593</td>
<td>12.6%</td>
<td>89.0%</td>
</tr>
</tbody>
</table>
Sample

Unbalanced sample (gender): need for corrections

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level</th>
<th>Targeted rate</th>
<th>Rate phase I</th>
<th>Rate phase II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Language</td>
<td>German</td>
<td>72.5%</td>
<td>67.3%</td>
<td>67.8%</td>
</tr>
<tr>
<td></td>
<td>French</td>
<td>23.0%</td>
<td>27.2%</td>
<td>26.6%</td>
</tr>
<tr>
<td></td>
<td>Italian</td>
<td>4.5%</td>
<td>5.6%</td>
<td>5.6%</td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>49.4%</td>
<td>74.0%</td>
<td>74.2%</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>50.6%</td>
<td>26.0%</td>
<td>25.8%</td>
</tr>
<tr>
<td>Age category</td>
<td>18-35 years</td>
<td>33.6%</td>
<td>23.0%</td>
<td>21.8%</td>
</tr>
<tr>
<td></td>
<td>36-55 years</td>
<td>41.6%</td>
<td>51.8%</td>
<td>52.6%</td>
</tr>
<tr>
<td></td>
<td>56-74 years</td>
<td>24.8%</td>
<td>25.2%</td>
<td>25.6%</td>
</tr>
</tbody>
</table>
Survey

Phase I
- Characteristics of car(s) of respondents household
- Socio-economic information
- Mobility habits

Phase II
- Opinions and perceptions on topics related to EV
- Choice situations
- Willingness-to-pay
- Interest in additional services
## Design of the choice experiment

<table>
<thead>
<tr>
<th>EV variable</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase price</td>
<td>( (P_{\text{gasoline}} + 5'000) \times 0.8 )</td>
<td>( (P_{\text{gasoline}} + 5'000) \times 1 )</td>
<td>( (P_{\text{gasoline}} + 5'000) \times 1.2 )</td>
<td>-</td>
</tr>
<tr>
<td>(&lt; 55 \text{ KCHF} )</td>
<td>( (P_{\text{Mégane}} + 5'000) \times 0.8 )</td>
<td>( (P_{\text{Mégane}} + 5'000) \times 1 )</td>
<td>( (P_{\text{Mégane}} + 5'000) \times 1.2 )</td>
<td>-</td>
</tr>
<tr>
<td>(\geq 55 \text{ KCHF} )</td>
<td>( -0 \text{ CHF} )</td>
<td>( -500 \text{ CHF} )</td>
<td>( -1'000 \text{ CHF} )</td>
<td>-</td>
</tr>
<tr>
<td>Governmental incentive</td>
<td>1.70 CHF</td>
<td>3.55 CHF</td>
<td>5.40 CHF</td>
<td>-</td>
</tr>
<tr>
<td>Cost of fuel/electricity for 100 km</td>
<td>85 CHF</td>
<td>105 CHF</td>
<td>125 CHF</td>
<td>-</td>
</tr>
<tr>
<td>Battery lease</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Segmentation

A priori higher interest for EV and/or Renault
- Pre-orders (1)
- Subscribers of the Z.E. newsletter (2)

A priori interest in Renault
- Renault customers (3)

No a priori interest for EV and/or Renault
- Recent buyers (4)
- Prospective buyers (5)
Model specification

- Explanatory variables:
  - Vehicle purchase price
  - Refueling / recharging costs
  - Battery lease
  - Incentive
  - Household composition
  - Frequent PT usage
  - High income
  - Age
  - Number of cars
  - Type of car buyer

- Utility

- Choice:
  - Own car
  - Brand A petrol-driven car
  - Electric car
### Parameter estimates

<table>
<thead>
<tr>
<th>Utilities</th>
<th>Competitor – Gasoline (CG)</th>
<th>Renault – Gasoline (RG)</th>
<th>Renault – Electric (RE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.0212**</td>
<td>Prix CG</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>-0.211</td>
<td></td>
<td>Price RG · TG1245</td>
<td>-</td>
</tr>
<tr>
<td>-0.598</td>
<td></td>
<td>Price RG · TG3</td>
<td>-</td>
</tr>
<tr>
<td>-0.404</td>
<td></td>
<td></td>
<td>Price RE · TG12</td>
</tr>
<tr>
<td>-1.00</td>
<td></td>
<td></td>
<td>Price RE · TG3</td>
</tr>
<tr>
<td>-0.628</td>
<td></td>
<td></td>
<td>Price RE · TG45</td>
</tr>
<tr>
<td>-0.049**</td>
<td>Operating cost gasoline</td>
<td>Operating cost gasoline</td>
<td>-</td>
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<table>
<thead>
<tr>
<th>Utilities</th>
<th>Competitor – Gasoline (CG)</th>
<th>Renault – Gasoline (RG)</th>
<th>Renault – Electric (RE)</th>
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</thead>
<tbody>
<tr>
<td>-0.252</td>
<td></td>
<td></td>
<td>High operating cost · Fluence</td>
</tr>
<tr>
<td>-0.778</td>
<td></td>
<td></td>
<td>High operating cost · Zoé</td>
</tr>
<tr>
<td>-0.447</td>
<td></td>
<td></td>
<td>Medium operating cost · Zoé</td>
</tr>
<tr>
<td>-0.205*</td>
<td></td>
<td></td>
<td>High battery lease</td>
</tr>
<tr>
<td>-0.0539**</td>
<td></td>
<td></td>
<td>Medium battery lease</td>
</tr>
<tr>
<td>0.73</td>
<td></td>
<td></td>
<td>High incentive</td>
</tr>
<tr>
<td>0.0803**</td>
<td></td>
<td></td>
<td>Medium incentive</td>
</tr>
<tr>
<td>-0.00224**</td>
<td></td>
<td></td>
<td>Low incentive</td>
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## Parameter estimates

<table>
<thead>
<tr>
<th>Utilities</th>
<th>Competitor - Gasoline (CG)</th>
<th>Renault - Gasoline (RG)</th>
<th>Renault - Electric (RE)</th>
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</thead>
<tbody>
<tr>
<td>-0.279</td>
<td>PT · TG1245</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>-0.552</td>
<td></td>
<td>PT · TG1245</td>
<td>-</td>
</tr>
<tr>
<td>-1.85</td>
<td>PT · TG3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>-1.07</td>
<td></td>
<td>PT · TG3</td>
<td>-</td>
</tr>
<tr>
<td>-0.217</td>
<td>Family with children</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.0454**</td>
<td></td>
<td>Family with children</td>
<td>-</td>
</tr>
<tr>
<td>-0.25</td>
<td>Income</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>-0.297</td>
<td></td>
<td>Income</td>
<td>-</td>
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<table>
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<tr>
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<th>Competitor - Gasoline (CG)</th>
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<th>Renault - Electric (RE)</th>
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</thead>
<tbody>
<tr>
<td>-0.172</td>
<td>Nb cars · TG1245</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>-0.157</td>
<td></td>
<td>Nb cars · TG1245</td>
<td>-</td>
</tr>
<tr>
<td>-0.384**</td>
<td>Nb cars · TG3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>-0.729</td>
<td></td>
<td>Nb cars · TG3</td>
<td>-</td>
</tr>
<tr>
<td>0.335</td>
<td>French</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.0876**</td>
<td></td>
<td>French</td>
<td>-</td>
</tr>
<tr>
<td>0.0124</td>
<td>Age</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>-0.00187**</td>
<td></td>
<td>Age</td>
<td>-</td>
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## Parameter estimates

<table>
<thead>
<tr>
<th>Utilities</th>
<th>Competitor – Gasoline (CG)</th>
<th>Renault – Gasoline (RG)</th>
<th>Renault – Electric (RE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.97</td>
<td>TG12</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1.04</td>
<td>-</td>
<td>TG12</td>
<td>-</td>
</tr>
<tr>
<td>-0.635</td>
<td>TG3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2.45</td>
<td>-</td>
<td>TG3</td>
<td>-</td>
</tr>
<tr>
<td>-2.12</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>-1.67</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>
Market shares and revenues
Outline

1 Motivation
- Literature review
- Need to model behavior
- Applications
- Importance

2 Some theory
- Decision rule

3 The random utility model

4 Questioning rationality

5 Choice data

6 Case studies
- Market shares of electrical vehicles
- Value of time
- Path to purchase

6 Conclusion
Value of time in Switzerland


Data collection

- Source for recruitment: survey “Kontinuierliche Erhebung zum Personenverkehr” (KEP) by SBB/CFF
- Stated preferences
- Questionnaire designed based on a real reference trip
- Three parts:
  - SP mode choice (car / bus or rail)
  - SP route choice (current mode or alternative mode)
  - Socio-demographics and information about the reference trip
## Value of time in Switzerland

### Mode choice car – rail (main study version)

<table>
<thead>
<tr>
<th></th>
<th>Car</th>
<th>Rail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel costs:</td>
<td>18 Fr.</td>
<td></td>
</tr>
<tr>
<td>Total travel time:</td>
<td>40 minutes</td>
<td></td>
</tr>
<tr>
<td>... congested:</td>
<td>10 minutes</td>
<td></td>
</tr>
<tr>
<td>... uncongested:</td>
<td>30 minutes</td>
<td></td>
</tr>
</tbody>
</table>

### Route choice rail (main study version)

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel costs:</td>
<td></td>
<td>20 Fr.</td>
</tr>
<tr>
<td>Travel time:</td>
<td></td>
<td>40 minutes</td>
</tr>
<tr>
<td>Headway:</td>
<td></td>
<td>15 minutes</td>
</tr>
<tr>
<td>No. of changes:</td>
<td></td>
<td>1 times</td>
</tr>
</tbody>
</table>
## Value of time in Switzerland

### Number of observations (1225 individuals)

<table>
<thead>
<tr>
<th>Route: Mode</th>
<th>Business</th>
<th>Commuters</th>
<th>Leisure</th>
<th>Shopping</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode: car/bus</td>
<td>6</td>
<td>162</td>
<td>186</td>
<td>126</td>
<td>480</td>
</tr>
<tr>
<td>Mode: car/rail</td>
<td>426</td>
<td>1716</td>
<td>2538</td>
<td>1104</td>
<td>5784</td>
</tr>
<tr>
<td>Route: bus for bus users</td>
<td>9</td>
<td>405</td>
<td>450</td>
<td>342</td>
<td>1206</td>
</tr>
<tr>
<td>Route: car for car users</td>
<td>156</td>
<td>846</td>
<td>1176</td>
<td>660</td>
<td>2838</td>
</tr>
<tr>
<td>Route: rail for car users</td>
<td>126</td>
<td>594</td>
<td>837</td>
<td>504</td>
<td>2061</td>
</tr>
<tr>
<td>Route: rail for rail users</td>
<td>324</td>
<td>1008</td>
<td>1881</td>
<td>288</td>
<td>3501</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1047</td>
<td>4731</td>
<td>7068</td>
<td>3024</td>
<td>15870</td>
</tr>
</tbody>
</table>
Value of time in Switzerland

Explanatory variables

- travel time
- travel cost
- level of congestion (car)
- frequency (TC)
- number of transfers (TC)
- trip length
- income
- inertia
- car availability
- sex
- 1/2-fare CFF
- general subscription
- trip purpose
## Value of time in Switzerland

<table>
<thead>
<tr>
<th></th>
<th>Business</th>
<th>Commute</th>
<th>Leisure</th>
<th>Shopping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time TC (CHF/h)</td>
<td>49.57</td>
<td>27.81</td>
<td>21.84</td>
<td>17.73</td>
</tr>
<tr>
<td>Time car (CHF/h)</td>
<td>50.23</td>
<td>30.64</td>
<td>29.20</td>
<td>24.32</td>
</tr>
<tr>
<td>Headway (CHF/h)</td>
<td>14.88</td>
<td>11.18</td>
<td>13.38</td>
<td>8.48</td>
</tr>
<tr>
<td>CHF/transfer</td>
<td>7.85</td>
<td>4.89</td>
<td>7.32</td>
<td>3.52</td>
</tr>
</tbody>
</table>
Value of time in Switzerland

VTTS
Public transport, business travellers

VTTS
Public transport, commuters

Distance (km)

Income (CHF)

100
90
80
70
60
50
40
30
20
10

250
200
150
100
50
10000
50000
100000
150000
200000
Value of time in Switzerland

Value of time varies (namely) with

- transportation mode,
- trip purpose,
- income,
- trip length.
Outline

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5 Choice data

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   - Market shares of electrical vehicles
   - Value of time
   - Path to purchase

6 Conclusion
Path to purchase: the case of ice-cream

Collaboration Nestlé-EPFL

- 2006–2008
- Nestlé
  - Nestlé Research Center
  - Ice cream Business Unit
- EPFL
  - Transport and Mobility Laboratory (Prof. Bierlaire)
  - Signal Processing Laboratory (Prof. Thiran)
Path to purchase

Project

- Impact of the stimuli on the consumers behavior
- Example: design of an ice cream board
Data collection

Eye tracking
Data processing

From raw video to numerical data
- Movie: Original video
- Movie: Correct distortions
- Identify locations
The model

Two phase model

Latent decision

Information acquisition

Decision validation

Choice model

Actual observed choice

End of sequence

\[ t_0 = 0 \quad t_1 \quad t_2 \quad t_3 \quad t_i \quad t_{i+1} \quad t_{i+2} \quad t_{i+3} = T \]
The model

Prior \rightarrow \text{Board design} \rightarrow \text{Fixation time (two phase model)} \rightarrow \text{Choice (discrete choice model)} \rightarrow \text{Socio-economics}
Results
Outline

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6 Conclusion
Conclusion

Behavioral models

- Individual choice model
- Disaggregate market segments
- Flexible specification
- Quantitative and qualitative variables
- Usage of revealed and stated preferences data
- Wide range of applications
- Can account for subjectivity (attitudes and perceptions)
Conclusion

Short course: Discrete Choice Analysis: Predicting Demand and Market Shares

March 23 – 27, 2014

- Ecole Polytechnique Fédérale de Lausanne
- Prof. Ben-Akiva (MIT)
- Prof. Bierlaire (EPFL)
- Prof. McFadden (UC Berkeley)
- Prof. Walker (UC Berkeley)
- transp-or.epfl.ch/dca