3. Stated choice analyses

3.1 Stated and revealed preference data

Revealed preference (RP) data:

- These data are based on actual decisions and choices in real-world situations, i.e. individuals reveal their tastes or preferences through their decisions in the world
- Examples: Actual voting behavior in referenda, actual purchases (e.g. from scanner panel data), actual financial investments, actual purchases of cars

Stated preference (SP) data:

- These data are collected in experiments or surveys and refer to situations where a decision or choice is made by considering hypothetical scenarios
- Example: Stated WTP for environmental policies, stated financial investments when several products with different returns and other attributes are presented, stated purchases of a car when several cars with different prices and other attributes are presented

→ RP data are often considered generally superior to SP data by economists since they refer to observations of real individual behavior and thus have a high reliability and validity

However, SP data have several advantages compared with RP data:

- In contrast to RP data, SP data are not limited to situations, products, and attributes of alternatives that currently exist or have existed in the past, but can also refer to new products (e.g. new energy sources in vehicles or new financial products), new attributes of products, or products with a low market penetration
- Even for already existing situations and products, it is possible that some relevant factors and thus explanatory variables have little variability (e.g. prices of products or interest rates in financial products) so that an econometric analysis is hardly possible with RP data. Instead, SP experiments can be designed to contain as much variation in attributes as desired.
- Explanatory variables for real-world decisions can be strongly correlated (e.g. fuel efficiency and motor power of cars are mostly strongly negatively correlated, price and quality of cars can be strongly positively correlated), which makes the econometric analysis with RP data problematic
- The collection of RP data can be very time consuming, very expensive, or even impossible for specific topics
- In particular, RP data are not or only indirectly available for valuations of public goods such as environmental goods (e.g. climate protection) since they are not traded in real economic markets so that e.g. the analysis of WTP for climate protection is problematic or impossible with RP data

Contingent valuation methods (CVM):

- In this SP approach mostly non-market resources (e.g. natural resources), which typically give some utility, are valued by respondents in a survey
- Typically, respondents are directly asked for the WTP for public goods such as for a new local recreation area or an improvement in environmental quality (e.g. an increase in biodiversity)
- The WTP questions in CVM can be based on classical open-ended formats or several types of (e.g. single or double bounded) binary choice formats
- A problem of CVM is that it strongly relies on the accuracy of the description of the resources (e.g. local recreation area) that are valued. Furthermore, CVM cannot value separate components or attributes of the resources.

Conjoint analyses:

- In this non-choice SP approach respondents rank or rate each combination of components or attributes of several alternatives such as products
- However, such ranking tasks are problematic with respect to utility theory, which do not necessarily reveal the WTP for some attributes. In particular, in real-world situations decision makers have to make specific choices (e.g. between several vehicles).

→ As a consequence, data from stated choice experiments (SCE), where respondents are asked to indicate their preference among two or more multi-attribute alternatives, are in many situations the most attractive SP data

3.2 Design of stated choice experiments

Overview of main components of SCE:

- Problem definition and development, i.e. analysis of the research questions (e.g. analysis of possible preferences and WTP for electric vehicles or for sustainable investments)
- Identification and selection of choice alternatives (e.g. different energy sources and propulsion technologies in vehicles, different investment products) including the decision for labeled or unlabeled alternatives
- Selection of attributes, attribute levels, and attribute-level labels
- Selection of experimental design, i.e. specification of how attribute levels are combined to form different alternatives
- Generation of choice sets, i.e. decision on how the attribute level combinations are blocked for the presentation to the respondents

Challenges in the survey and questionnaire construction (which does not only comprise an SCE, but also other questions) for reliable econometric analyses:

- Generally, the survey design should strongly conform to the problem definition and not vice versa, i.e. the research question should not be adjusted to the survey design
- The questions must correspond to the type of data that are necessary for the econometric models (e.g. linear or nonlinear) in the empirical analysis

- The questions must be appropriate for the study, i.e. questions that are not used in the econometric analysis unnecessarily extend the length of the survey (and thus the costs and the efforts for the respondents)
- The questions must be understandable, realistic, and unambiguous for the respondents and should not be based on specific technical expertise (e.g. with respect to different energy sources and propulsion technologies in vehicles)
- Biased and leading questions as well as non-mutually exclusive categories in the SCE should be avoided
- The decision context in the SCE should be clear, i.e. a descriptive story should be provided that explains the context in which to consider the choice of the different alternatives (e.g. it should be clarified whether holiday or business trips are considered for the choice among different travel modes)
- The survey delivery method must be appropriate, e.g. phone surveys generally make no sense for SCE since the questions are too complex. While (computer-assisted) personal interviews are attractive, they can be very expensive so that recently often online surveys are conducted instead of written surveys, which were very attractive in the past.
- Finally, the whole questionnaire should be thoroughly tested before data collection, e.g. on the basis of expert talks, focus groups, and especially pretests with a small sample from the interesting population

Hypothetical bias:

In order to circumvent or at least reduce problems through the hypothetical character of SCE or general SP data (especially the overestimation of WTP), several ex ante procedures are often included to increase the validity of SCE data such as cheap talk scripts (e.g. the advice that the income and wealth situation should be strongly considered in the SCE) or honesty oaths

Labeled and unlabeled SCE:

- Labeled SCE assign specific labels to each alternative (e.g. air, train, bus, car in travel mode choices or electric, gasoline, diesel cars in the choice among different energy sources and propulsion technologies in vehicles)
- Unlabeled SCE use generic or uninformative titles or headings for the alternatives (e.g. alternative 1, alternative 2, etc.) and thus do not give additional information to the respondent
- A label for an alternative can be considered like an attribute, which is speci-fically obvious in quasi-labeled SCE, where each alternative refers to exactly one specification (e.g. when electric, gasoline, and diesel are included as at-tribute levels for the attribute energy sources and propulsion technologies)
- One advantage of unlabeled SCE is that they do not require the identification and use of all alternatives among the universal set of alternatives
- However, labeled SCE can sometimes be more realistic and also be useful for the estimation of alternative-specific constants

Experimental designs:

- Full factorial design
  - Design in which all possible attribute level combinations (which can be differently coded) are considered
  - Example: For two attributes (e.g. purchase price and CO_2 emissions) with three levels, respectively (e.g. 5000, 10000, 15000 Euro and 0, 100, 200 gram per kilometer) in the case of a vehicle choice, nine (i.e. 3·3) attribute level combinations for one alternative are possible
  - In general, the number of possible attribute level combinations depends on the number L of attribute levels, the number k_2 of attributes, and the number J of alternatives and thus is $L^{k_2 J}$ in labeled SCE and L^{k_2} in unlabeled SCE
  - It is important to note that the alternatives in labeled SCE often have different attributes and especially different attribute levels (e.g. 0, 100, 200 gram CO_2 emissions per kilometer for electric vehicles, but only 100 and 200 gram for gasoline vehicles)
  - Full factorial designs have very attractive statistical properties for parameter estimation and statistical testing, but the number of attribute level combinations is mostly too large in practice so that commonly only a fraction of them is used

- Fractional factorial design
  - Design in which only a fraction of all possible attribute level combinations is used
  - While it is possible to randomly select a specific number of combinations, this can lead to inefficient or sub-optimal designs
  - Instead, several scientific methods can be used to select more sophistica-ted optimal attribute level combinations
  - One popular approach is the orthogonal fractional factorial design, which is generated such that the attributes of the design are uncorrelated. How-ever, the minimization of the correlations in this design generally does not lead to the statistically most efficient design.
- Optimal or statistically efficient designs
  - Optimal designs often allow for correlations across the attributes, but are statistically efficient
  - A popular criterion is the determinant of the variance-covariance matrix of the parameter vector that is estimated with ML in a model. The maximiza-tion of this determinant leads to D-optimal designs.
  - The value of this determinant (i.e. of the determinant of the inverse of the variance-covariance matrix) is the basis for the calculation of the level of D-efficiency

Generation and selection of choice sets:

- Each attribute level combination from the experimental design is a separate potential choice set and thus provides the relevant information about the alternatives, attributes, and attribute levels in the hypothetical scenario
- In each choice set it is important that the attribute levels are well defined and clear for the respondents so that a mechanism of describing unambiguously each attribute level is required. One common approach is the inclusion of pictures (e.g. for the description of colors as attribute for cars).
- It is important to ensure that the decision in each choice set is independent to the decisions in all other choice sets, i.e. that the hypothetical scenarios in the choice sets cannot be compared
- Finally, a specific number (e.g. six or 12) of the possible choice sets from the experimental design must be randomly assigned to the respondents

No choice option:

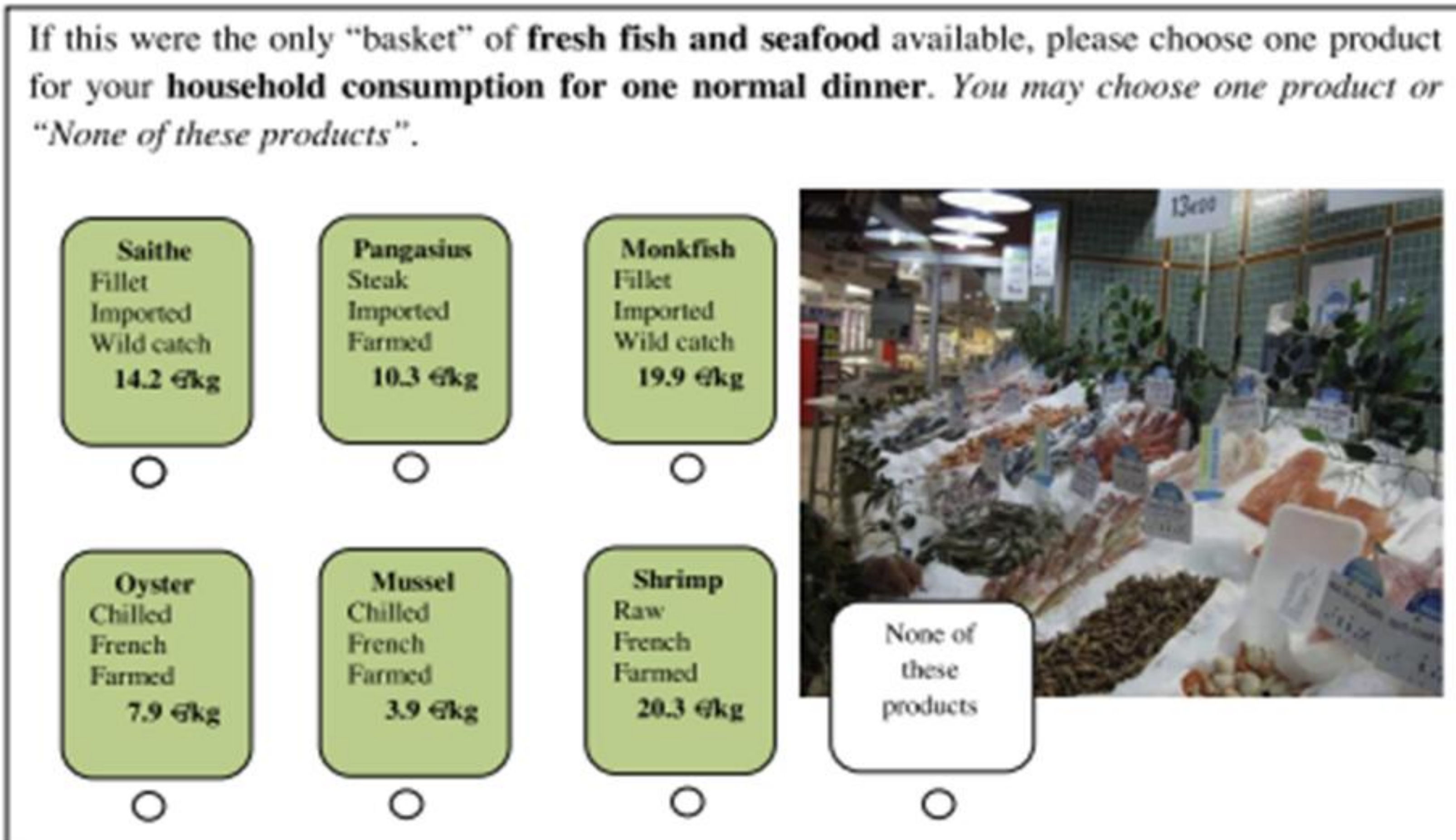
The decision whether to include the option to not choose an alternative should be based on the objective of the study. For example, if the demand for different alternatives in a market is considered, the inclusion of the no choice alternative is mostly useful, whereas the inclusion of the no choice option can be hindering in an analysis of the effect of different attribute levels. Without the no choice alternative, the analyzed decision is a conditional choice, i.e. conditional on choosing any alternative.

It is often (especially in the case of the valuation of public goods) useful to include the status quo (i.e. baseline) alternative besides other alternatives:

- In some cases, the inclusion of the status quo alternative as additional alternative represents an inclusion of RP data in SCE (e.g. in the choice among different electricity tariffs, the current electricity tariff can be included)
- The information of the current status quo alternative must be collected before the SCE in the survey so that it can be included in the experiment
- In contrast to the other alternatives, the status quo alternative and its attribute levels remain constant across all choice sets for the same respondent
- The individual attribute levels are often coordinated with the levels in the status quo to make the hypothetical scenarios more realistic for the respondent (e.g. the electricity costs as an attribute in the choice among different electricity tariffs can be very different across households)
- These customized attribute levels (which need not refer to the inclusion of the status quo alternative) are mostly based on percentage changes from the status quo levels (e.g. -10%, 0%, +10% of the current electricity costs)
- Commonly, not the percentage changes, but the respective values that are linked with the percentage changes are presented in the choice sets (e.g. 550 Euro instead of +10%, when 500 Euro is the cost value in the status quo), which can lead to very different values across the respondents

3.3 Examples

Choice set of a labeled SCE, i.e. choice among the six fresh fish and seafood alternatives saithe, pangasius, monkfish, oyster, mussel, and shrimp including a no choice option (see Nguyen et al., 2015, *Food Quality and Preference*, 225-236):



Choice set of a labeled SCE, i.e. choice among a conventional vehicle and three electric vehicles, i.e. a pure electric vehicle, an electric vehicle with range extender, and a plug-in hybrid vehicle (see Kanberger and Ziegler, 2024, *Transportation Research Part D* 126, 104031):

Let us start with the first set of choices. Which of the following four cars would you most likely choose?				
	Vehicle 1: Pure electric vehicle [Mouse click: Car powered exclusively by one or more electric motors]	Vehicle 2: Electric vehicle with range extender [Mouse click: Car powered by a combination of one or more electric motors plus a small gasoline or diesel engine for range extension]	Vehicle 3: Gasoline or diesel vehicle [Mouse click: Car powered exclusively by a gasoline or diesel engine]	Vehicle 4: Plug-in hybrid vehicle [Mouse click: Car powered by a combination of one or more small electric motors and a gasoline or diesel engine]
CO_2 emissions in use per 100 km	10.1 kg	11.2 kg	22.9 kg	21.2 kg
CO_2 emissions in the production	5,000 kg	5,800 kg	6,000 kg	8,600 kg
Range with a fully charged battery	300 km	400 km	-	150 km
Range with a full tank	-	50 km	900 km	400 km
Time to recharge the battery	180 minutes	60 minutes	-	120 minutes
Time to refuel the tank	-	2 minutes	3 minutes	5 minutes
Fuel costs per 100 km	3.50 Euro	7.20 Euro	5.50 Euro	7.50 Euro
Purchase price	8,400 Euro	15,600 Euro	14,400 Euro	12,000 Euro
My choice	□	□	□	□
Would you rather not choose any of the cars shown above and prefer another car instead? □ Yes □ No				

Choice set of an unlabeled SCE, i.e. choice among three electricity tariffs including the five attributes location of electricity provider, electricity mix, guaranteed share of regionally generated electricity, customized electricity costs per year, type of electricity provider:

<table>
<tr><td colspan="4">Please indicate the contract that you would most likely make among the following three contracts:</td></tr>
<tr><td></td><td>Contract 1</td><td>Contract 2</td><td>Contract 3</td></tr>
<tr><td>Location of the electricity provider</td><td>Within the own region</td><td>Outside the own region</td><td>Outside the own region</td></tr>
<tr><td>Energy mix in the chosen tariff</td><td>100% renewable energies (electricity provider sells both electricity from renewable energy sources and electricity produced from nuclear energy or fossil energy sources)</td><td>100% renewable energies (electricity provider only sells electricity from renewable energy sources)</td><td>Mix of renewable energies, fossil energy sources, and nuclear energy</td></tr>
<tr><td>Guaranteed share of electricity in the mix of the chosen contract that is produced within the own region</td><td>100%</td><td>0%</td><td>50%</td></tr>
<tr><td>Annual electricity costs</td><td>792 € / year</td><td>504 € / year</td><td>648 € / year</td></tr>
<tr><td>Type of the electricity provider</td><td>German national electricity provider</td><td>Foreign electricity supplier</td><td>Municipal or regional utility</td></tr>
<tr><td></td><td>□</td><td>□</td><td>□</td></tr>
<tr><td colspan="4">Would you rather choose none of the previous electricity contracts and instead remain your current electricity contract?
□ Yes
□ No</td></tr>
</table>

Choice set of an unlabeled SCE, i.e. choice among two wind energy policy options including a no choice option (see Dimitropoulos and Kontoleon, 2009, *Energy Policy*, 1842-1854):

	Policy Option A	Policy Option B	None of them
Wind Farm Size	7-13 Wind turbines	21-40 Wind turbines	
Wind Turbine Height	90 meters	90 meters	
Sited in a Special Protection/Conservation Area	Yes	No	No new wind turbine
Cooperation/Deliberation during the Planning Procedure	No cooperation with the municipal authorities and local representatives	No cooperation with the municipal authorities and local representatives	
Annual Subsidy per Household	€100	€300	No Subsidy
Choose your most preferred option ➔	☐	☐	☐

Choice set of an unlabeled SCE, i.e. choice among three new policy packages for the German energy transition and the status quo option with the five attributes targeted share of renewable energies until 2025, nuclear phase-out until 2022, burden sharing of the costs of the energy transition, financial support for low-income households, additional or reduced costs compared to the status quo (see Kanberger and Ziegler, 2023, *Energy Policy* 182, 113730):

Criteria	Policy package 1	Policy package 2	Policy package 3	None of the three policy packages (i. e. currently planned measures of the energy transition)
Targeted share of renewable energies in the power generation by 2025	40–45%	30–35%	55–60%	40–45%
Phase-out of all nuclear power plants by 2022	No	No	Yes	Yes
Participation of households in the costs of the energy transition	Each person should bear the same cost burden	Each household should bear costs in relation to its income	Each household should bear costs in relation to its energy consumption	Each household should bear costs in relation to its energy consumption
Financial support for low-income households	Financial support for the 10% poorest households	Financial support for the 30% poorest households	No financial support	No financial support
Additional or reduced monthly costs for your household compared to the currently planned measures of the energy transition	100 Euro more	50 Euro more	20 Euro more	The same costs
Your choice (please select your preferred policy package)	☐	☐	☐	☐

3.4 Econometric analysis

Due to the additional dimension of several choice sets for each respondent, the utility function in SCE has to be extended, i.e. the general utility (allowing for a random parameter specification) of respondent i (i = 1,…, n) for alternative j (j = 1,…, J) in choice set c (c = 1,…, C) has a panel structure and thus is in the most general case:

$$u_{ijc} = \beta_{ij}^{'} x_i + \gamma_i^{'} z_{ijc} + \varepsilon_{ijc}$$

The realizations of the following dummy variables can be observed:

$$y_{ijc} = \begin{cases} 1 & \text{if i chooses j in choice set c} \\ 0 & \text{otherwise} \end{cases}$$

It is assumed that individual i chooses category j in choice set c if the utility of alternative j is the largest of all utilities, i.e. $u_{ijc} > u_{ij'c}$ (i = 1,…, n; c = 1,…, C; j, j' = 1,…, J, j ≠ j')

The parameter vectors β_{ij} and γ_i are again summarized in δ_i. Furthermore, by summarizing the k_2-dimensional vectors z_{ijc} in the J·C·k_2-dimensional vector z_i and then the k_1-dimensional vector x_i and z_i in the (k_1+J·C·k_2)-dimensional vector X_i, the probabilities that i chooses j in c are:

$$p_{ijc}(X_i, \delta_i) = P(y_{ijc}=1|X_i, \delta_i) = P(u_{ijc} > u_{ij'c};\ \forall j \neq j'|X_i, \delta_i)$$

Multinomial logit models:

- In this case, the parameter vectors β_{ij} and γ_i are fixed so that it follows for the utility function:

$$u_{ijc} = \beta_j^{'} x_i + \gamma^{'} z_{ijc} + \varepsilon_{ijc}$$

- The β_j are again summarized in the $J \cdot k_2$-dimensional vector β. The assumption that the error terms ε_{ijc} are independently and identically standard extreme value distributed across all j = 1,…, J and all c = 1,…, C (and naturally also across all i = 1,…, n) leads to the following choice probabilities:

$$p_{ijc}(X_i, \beta, \gamma) = P(y_{ijc}=1|X_i, \beta, \gamma) = \frac{e^{\beta_j^{'} x_i + \gamma' z_{ijc}}}{\sum_{m=1}^{J} e^{\beta_m^{'} x_i + \gamma' z_{imc}}}$$

- It follows for the log-likelihood function and the ML estimator:

$$\log L(\theta) = \sum_{i=1}^{n} \sum_{j=1}^{J} \sum_{c=1}^{C} y_{ijc} \log p_{ijc}(X_i, \beta, \gamma)$$

$$\hat{\theta}_{ML} = \arg\max_{\theta} \left[\sum_{i=1}^{n} \sum_{j=1}^{J} \sum_{c=1}^{C} y_{ijc} \log p_{ijc}(X_i, \beta, \gamma) \right]$$

- However, the use of multinomial logit models on the basis of SCE data is even more restrictive since they do not only assume independence of the error terms over the J alternatives, but also over the C choice sets

Multinomial probit models:

- As in the case of multinomial logit models the utility function is:

$$u_{ijc} = \beta_j' x_i + \gamma' z_{ijc} + \varepsilon_{ijc}$$

- By assuming that the error terms ε_{ijc} are jointly normally distributed with expectation zero and a J·C-dimensional variance covariance matrix ∑, the choice probabilities for a specific choice set c are characterized by a (J-1)-dimensional integral:

$$\begin{aligned} p_{ijc}(X_i, \beta, \gamma, \Sigma) = P\Big(& \varepsilon_{i1c} - \varepsilon_{ijc} < (\beta_j' x_i + \gamma' z_{ijc}) - (\beta_1' x_i + \gamma' z_{i1c}); \ldots; \\ & \varepsilon_{i,j-1,c} - \varepsilon_{ijc} < (\beta_j' x_i + \gamma' z_{ijc}) - (\beta_{j-1}' x_i + \gamma' z_{i,j-1,c}); \\ & \varepsilon_{i,j+1,c} - \varepsilon_{ijc} < (\beta_j' x_i + \gamma' z_{ijc}) - (\beta_{j+1}' x_i + \gamma' z_{i,j+1,c}); \ldots; \\ & \varepsilon_{iJc} - \varepsilon_{ijc} < (\beta_j' x_i + \gamma' z_{ijc}) - (\beta_J' x_i + \gamma' z_{iJc}) \Big) \end{aligned}$$

$$= \int_{-\infty}^{(\beta_j' x_i + \gamma' z_{ijc}) - (\beta_1' x_i + \gamma' z_{i1c})} \cdots \int_{-\infty}^{(\beta_j' x_i + \gamma' z_{ijc}) - (\beta_{j-1}' x_i + \gamma' z_{i,j-1,c})} \int_{-\infty}^{(\beta_j' x_i + \gamma' z_{ijc}) - (\beta_{j+1}' x_i + \gamma' z_{i,j+1,c})} \cdots \int_{-\infty}^{(\beta_j' x_i + \gamma' z_{ijc}) - (\beta_J' x_i + \gamma' z_{iJc})}$$

$$\varphi_j(\omega_{1c}, \ldots, \omega_{j-1,c}, \omega_{j+1,c}, \ldots, \omega_{J,c})\, d\omega_{1c} \cdots d\omega_{j-1,c}\, d\omega_{j+1,c} \cdots d\omega_{Jc}$$

- If these choice probabilities are included in the likelihood or log-likelihood functions as in the case of multinomial logit models, it is assumed that the error terms are independent across all choice sets

- Generally, each individual has to decide among J^C alternative sequences across all C choice sets, i.e. in each choice set c a respondent has to choose one alternative j_{ic} (with j_{ic} = 1,…, J). For flexible correlations across ε_{ijc} it follows for the probability that individual i chooses a specific category sequence s across all C choice sets:

$$\begin{aligned}
p_{is}(X_i, \beta, \gamma, \Sigma) &= P(u_{ij_{ic}c} > u_{ikc};\ k, j_{ic} = 1,..., J;\ k \neq j_{ic};\ \forall c;\ X_i, \beta, \gamma) \\
&= P\Big(\varepsilon_{i11} - \varepsilon_{ij_{i1}1} < (\beta'_{j_{i1}} - \beta'_1)x_{i1} + \gamma'(z_{ij_{i1}1} - z_{i11});\ldots; \\
&\quad \varepsilon_{i,j_{i1}-1,1} - \varepsilon_{ij_{i1}1} < (\beta'_{j_{i1}} - \beta'_{j_{i1}-1})x_{i1} + \gamma'(z_{ij_{i1}1} - z_{i,j_{i1}-1,1}); \\
&\quad \varepsilon_{i,j_{i1}+1,1} - \varepsilon_{ij_{i1}1} < (\beta'_{j_{i1}} - \beta'_{j_{i1}+1})x_{i1} + \gamma'(z_{ij_{i1}1} - z_{i,j_{i1}+1,1});\ldots; \\
&\quad \varepsilon_{iJ1} - \varepsilon_{ij_{i1}1} < (\beta'_{j_{i1}} - \beta'_J)x_{i1} + \gamma'(z_{ij_{i1}1} - z_{iJ1});\ldots\ldots; \\
&\quad \varepsilon_{i1C} - \varepsilon_{ij_{i1}C} < (\beta'_{j_{iC}} - \beta'_1)x_{iC} + \gamma'(z_{ij_{iC}1} - z_{i1C});\ldots \\
&\quad \varepsilon_{i,j_{iC}-1,C} - \varepsilon_{ij_{iC}C} < (\beta'_{j_{iC}} - \beta'_{j_{iC}-1})x_{iC} + \gamma'(z_{ij_{iC}1} - z_{i,j_{iC}-1,C}); \\
&\quad \varepsilon_{i,j_{iC}+1,C} - \varepsilon_{ij_{iC}C} < (\beta'_{j_{iC}} - \beta'_{j_{iC}+1})x_{iC} + \gamma'(z_{ij_{iC}1} - z_{i,j_{iC}+1,C});\ldots; \\
&\quad \varepsilon_{iJC} - \varepsilon_{ij_{iC}C} < (\beta'_{j_{iC}} - \beta'_J)x_{iC} + \gamma'(z_{ij_{iC}1} - z_{iJC})\Big) \\
&= \int_{-\infty}^{(\beta'_{j_{i1}}x_{i1} + \gamma' z_{ij_{i1}1}) - (\beta'_1 x_{i1} + \gamma' z_{i11})} \cdots\cdots \int_{-\infty}^{(\beta'_{j_{iC}}x_{iC} + \gamma' z_{ij_{iC}1}) - (\beta'_J x_{iC} + \gamma' z_{iJC})} \\
&\quad \varphi_s(\omega_{11},\ldots,\omega_{j_{i1}-1,1},\omega_{j_{i1}+1,1},\ldots,\omega_{J1},\ldots\ldots,\omega_{1C},\ldots,\omega_{j_{iC}-1,C},\omega_{j_{iC}+1,C},\ldots,\omega_{JC}) \\
&\quad d\omega_{11}\cdots d\omega_{j_{i1}-1,1}\, d\omega_{j_{i1}+1,1}\cdots d\omega_{J1}\cdots\cdots d\omega_{1C}\cdots d\omega_{j_{iC}-1,C}\, d\omega_{j_{iC}+1,C}\cdots d\omega_{JC}
\end{aligned}$$

- Dependent on the category sequence s, $\varphi_s(\cdot)$ is the joint density function of the normally distributed differences of ε_{ijc}. The choice probabilities are now characterized by (J-1)·C-dimensional integrals in the most flexible approaches.
- However, the huge number of variance covariance parameters even for moderate values of J and C can hardly be identified in practice, i.e. in the estimation procedure
- Against this background, some panel data approaches (i.e. multiperiod multinomial probit models) include some structure in the variance covariance parameters (besides the relationships between the alternatives) which refer to unobserved heterogeneity and intertemporal autoregressive correlations. In the case of SCE these correlations refer to taste persistence and memory effects across the choice sets, i.e.:

$$\varepsilon_{ijc} = \alpha_{ij} + v_{ijc} \quad \text{with} \quad v_{ijc} = \rho_j v_{i,j,c-1} + \sqrt{1-\rho_j^2}\,\eta_{ijc}$$

- The normally distributed η_{ijc} comprise correlations between the alternatives, the ρ_j denote autocorrelation coefficients and thus possible memory effects, and the normally distributed α_{ij} represent stochastic effects that are invariant across the choice sets and thus refer to taste persistence
- Such approaches strongly decrease the number of model parameters compared to the case without variance covariance structure

- In the general case, the choice probabilities have again to be simulated (e.g. by the GHK simulator) with $\tilde{p}_{is}(X_i, \beta, \gamma, \Sigma)$
- For the SML estimation, the following observable dummy variables are defined:

$$y_{is} = \begin{cases} 1 & \text{if i chooses alternative sequence s} \\ 0 & \text{otherwise} \end{cases}$$

- It follows for the specific simulated log-likelihood function and the SML estimator:

$$\log\tilde{L}(\beta, \gamma, \Sigma) = \sum_{i=1}^{n}\sum_{s} y_{is}\log\tilde{p}_{is}(X_i, \beta, \gamma, \Sigma)$$

$$\hat{\theta}_{SML} = \arg\max_{\theta}\left[\sum_{i=1}^{n}\sum_{s} y_{is}\log\tilde{p}_{is}(X_i, \beta, \gamma, \Sigma)\right]$$

- While the simplifying approaches as discussed above strongly decrease the number of model parameters in the SML estimation, they are mostly not included in common econometric software packages such as Stata (only correlations across the alternatives are considered), which makes the use of multinomial probit models for SCE data less attractive than the use of mixed logit models

Mixed logit models:

- By assuming that the ε_{ijc} are independently and identically standard extreme value distributed and the parameter vectors β_{ij} and γ_i (summarized in δ_i) are random, it follows for the conditional choice probabilities:

$$p_{ijc}(X_i|\delta_i) = P(y_{ijc}=1|X_i, \delta_i) = \frac{e^{\beta_{ij}^{'} x_i + \gamma_i^{'} z_{ijc}}}{\sum_{m=1}^{J} e^{\beta_{im}^{'} x_i + \gamma_i^{'} z_{imc}}}$$

- Especially with respect to unlabeled SCE, however, it is more common to only consider choice probabilities with alternative specific attributes:

$$p_{ijc}(X_i|\gamma_i) = \frac{e^{\gamma_i^{'} z_{ijc}}}{\sum_{m=1}^{J} e^{\gamma_i^{'} z_{imc}}}$$

- If $p_{ij_{ic}c}(X_i|\gamma_i)$ symbolizes the conditional probability that a specific alternative j_{ic} (with j_{ic} = 1,…, J) is chosen by respondent i in choice set c, the joint conditional probabilities of the observed sequence s of choices across all C choice sets are:

$$p_{is}(X_i|\gamma_i) = \prod_{c=1}^{C} p_{ij_{ic}c}(X_i|\gamma_i) = \prod_{c=1}^{C} \frac{e^{\gamma_i^{'} z_{ij_{ic}c}}}{\sum_{m=1}^{J} e^{\gamma_i^{'} z_{imc}}}$$

- If follows for the unconditional choice probabilities:

$$p_{is}(X_i) = \int \prod_{c=1}^{C} \frac{e^{\gamma' z_{ij_{ic}c}}}{\sum_{m=1}^{J} e^{\gamma' z_{imc}}} f(\gamma) d\gamma$$

- If f(γ|b, W) is the density function of normally distributed vectors with expectation b and variance covariance matrix W, it specifically follows:

$$p_{is}(X_i, b, W) = \int \prod_{c=1}^{C} \frac{e^{\gamma' z_{ij_{ic}c}}}{\sum_{m=1}^{J} e^{\gamma' z_{imc}}} \varphi(\gamma|b, W) d\gamma$$

- These probabilities can again be approximated by the mixed logit model simulator:

$$\tilde{p}_{is}(X_i, b, W) = \frac{1}{R} \sum_{r=1}^{R} \prod_{c=1}^{C} \frac{e^{\gamma_r' z_{ij_{ic}c}}}{\sum_{m=1}^{J} e^{\gamma_r' z_{imc}}}$$

- It follows for the specific SML estimator:

$$\hat{\theta}_{SML} = \arg\max_{\theta} \left[\sum_{i=1}^{n} \log \left(\frac{1}{R} \sum_{r=1}^{R} \prod_{c=1}^{C} \frac{e^{\gamma_r' z_{ij_{ic}c}}}{\sum_{m=1}^{J} e^{\gamma_r' z_{imc}}} \right) \right]$$

Latent class logit models:

- The basis is the following utility function of respondent i for alternative j in choice set c with only alternative specific attributes:

$$u_{ijc} = \gamma_q^{'} z_{ijc} + \varepsilon_{ijc}$$

- By assuming that the ε_{ijc} are independently and identically standard extreme value distributed, it follows for the probabilities that i chooses j in choice set c under the condition that i belongs to class q:

$$p_{ijcq}\left(z_i | \gamma_q\right) = \frac{e^{\gamma_q^{'} z_{ijc}}}{\sum_{m=1}^{J} e^{\gamma_q^{'} z_{imc}}}$$

- If $p_{ij_{ic}cq}(X_i|\gamma_i)$ symbolizes the conditional probability that a specific alternative j_{ic} (with j_{ic} = 1,…, J) is chosen by respondent i in class q in choice set c, the joint conditional probabilities of the observed sequence s of choices across all C choice sets are:

$$p_{iqs}(z_i|\gamma_q) = \prod_{c=1}^{C} p_{ij_{ic}cq}(z_i|\gamma_q) = \prod_{c=1}^{C} \frac{e^{\gamma_q^{'} z_{ij_{ic}c}}}{\sum_{m=1}^{J} e^{\gamma_q^{'} z_{imc}}}$$

- By including the multinomial logit model formula in the class membership model, the probability that i belongs to class q is again:

$$H_{iq} = \frac{e^{\beta_q' x_i}}{\sum_{q'=1}^{Q} e^{\beta_{q'}' x_i}}$$

- It follows for the unconditional probabilities of the observed sequence s of choices across all M choice sets:

$$p_{is}(z_i) = \sum_{q=1}^{Q} H_{iq} p_{iqs}(z_i|\gamma_q) = \sum_{q=1}^{Q} \left[\frac{e^{\beta_q' x_i}}{\sum_{q'=1}^{Q} e^{\beta_{q'}' x_i}} \prod_{c=1}^{C} \frac{e^{\gamma_q' z_{ij_{ic}c}}}{\sum_{m=1}^{J} e^{\gamma_q' z_{imc}}} \right]$$

- Finally, it follows for the ML estimator:

$$\hat{\theta}_{ML} = \arg\max_{\theta} \left[\sum_{i=1}^{n} \log \left(\sum_{q=1}^{Q} \left[\frac{e^{\beta_q' x_i}}{\sum_{q'=1}^{Q} e^{\beta_{q'}' x_i}} \prod_{c=1}^{C} \frac{e^{\gamma_q' z_{ij_{ic}c}}}{\sum_{m=1}^{J} e^{\gamma_q' z_{imc}}} \right] \right) \right]$$

3.5 Applications

Example 1: Energy sources and propulsion technologies in vehicles (I)

In Ziegler (2012, *Transportation Research Part A* 46, 1372-1385), an SCE (that is based on a computer-randomized fractional factorial design) with respect to the preferences for alternative energy sources or propulsion technologies in vehicles is examined:

- The data stem from Computer Assisted Personal Interviews (CAPI), conducted in selected car dealerships and technical inspection agencies (TÜV) between August 2007 and March 2008
- 598 persons from the population of German residents with valid drivers' licenses, who intend or at least could imagine to purchase a vehicle in the near future, participated in the survey
- The people were asked for details (e.g. size, motor power) of the currently used and future vehicle as well as for socio-demographic variables (e.g. age, gender, education)
- The SCE comprises six choice sets with seven hypothetical vehicles types
- It is a quasi-labeled experiment, i.e. each of the seven vehicles refers to exactly one energy source or propulsion technology
- The vehicles were additionally characterized by five attributes

---

Example 1: Energy sources and propulsion technologies in vehicles (II)

Alternatives:

- Gasoline
- Diesel
- Hybrid
- Gas (i.e. natural gas, liquid petroleum gas)
- Biofuel
- Hydrogen
- Electric

Further attributes:

- Purchase price (in Euro)
- Motor power (in horsepower)
- Fuel costs (in Euro per 100 kilometers)
- CO_2 emissions (in gram per kilometer)
- Service station availability (in % of stations with respective fuel)

Example 1: Energy sources and propulsion technologies in vehicles (III)

Attribute levels:

- Customized purchase price: 75%, 100%, 125% of stated values for all vehic-le types
- Customized motor power: 75%, 100%, 125% of stated values for all vehicle types
- Fuel costs: 5 Euro, 10 Euro, 20 Euro for all vehicle types
- CO_2 emissions: 90 gram, 170 gram, 250 gram for gasoline, diesel, hybrid, and gas vehicles, „no emissions“, 90 gram, 170 gram, 250 gram for biofuel, hydrogen, and electric vehicles
- Service station availability: 60%, 100% for gasoline and diesel vehicles, 20%, 60%, 100% for hybrid, gas, biofuel, hydrogen, and electric vehicles

Dependent variable:

Choice between gasoline, diesel, hybrid, gas, biofuel, hydrogen, and electric vehicles, whereby gasoline vehicles is chosen as base category

---

Example 1: Energy sources and propulsion technologies in vehicles (IV)

Alternative specific attributes:

- Purchase price in two variants
  - Divided by 100000 (price_100000)
  - In decimals with respect to the customization (price_decimal)
- Motor power in two variants
  - Divided by 1000 (motorpower_1000)
  - In decimals with respect to the customization (motorpower_decimal)
- Fuel costs divided by 100 (fuelcosts_100)
- CO_2 emissions divided by 1000 (CO2emissions_1000)
- Service station availability divided by 100 (servicestation_100)

Individual characteristics:

- Age in years divided by 100 (age_100)
- Gender dummy (male)
- Dummy for environmental-friendly purchases (environment_friendly)

Example 1: Energy sources and propulsion technologies in vehicles (V)

The following estimations are considered:

- ML estimation of the conditional logit model and SML estimation (with R = 50) of the independent multinomial probit model (with robustly estimated variances) with all alternative specific attributes (two different variants, respectively) and alternative specific constants
- ML estimation of the full multinomial logit model (without robustly estimated variances and with price_decimal and motorpower_decimal)
- A Hausman-McFadden test (but SML estimations of more flexible full multinomial probit model mostly do not converge to a maximum)
- SML estimation of a mixed logit model (with R = 100 Halton draws and robustly estimated variances) with all alternative specific attributes and alternative specific constants, whereby the parameters of the alternative specific attributes (except price_decimal) are assumed to be normally distributed
- SML estimation of a full mixed logit model (with R = 5 Halton draws), whereby the parameters of the alternative specific attributes are normally distributed (except for price_decimal)
- Simulated likelihood ratio test for the validity of a multinomial logit model
- Estimation of several WTP

Example 1: Energy sources and propulsion technologies in vehicles (VI)

```
asclogit choice price_100000 motorpower_1000 fuelcosts_100 CO2emissions_1000 servicestation_100, case(choiceset)
alternatives(alternatives) base(gasoline) robust

Alternative-specific conditional logit         Number of obs      =      25116
Case variable: choiceset                       Number of cases    =       3588

Alternative variable: alternatives             Alts per case: min =          7
                                                              avg =        7.0
                                                              max =          7

                                                  Wald chi2(5)    =    1092.67
Log pseudolikelihood = -6115.6117                 Prob > chi2     =     0.0000

                                    (Std. Err. adjusted for clustering on choiceset)
------------------------------------------------------------------------------------
                   |               Robust
            choice |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------------+----------------------------------------------------------------
alternatives       |
      price_100000 |  -3.689678   .3617452   -10.20   0.000    -4.398685    -2.98067
   motorpower_1000 |   5.942402   .6453878     9.21   0.000     4.677466    7.207339
     fuelcosts_100 |  -7.528909   .3306354   -22.77   0.000    -8.176943   -6.880876
 CO2emissions_1000 |  -4.124038   .2818152   -14.63   0.000    -4.676386   -3.571691
servicestation_100 |   1.232526   .0607206    20.30   0.000     1.113516    1.351537
-------------------+----------------------------------------------------------------
biofuel            |
             _cons |  -.6258317   .0707213    -8.85   0.000    -.7644428   -.4872205
-------------------+----------------------------------------------------------------
diesel             |
             _cons |   .0869089   .0549912     1.58   0.114    -.0208719    .1946896
-------------------+----------------------------------------------------------------
electric           |
             _cons |  -.9183785   .0760347   -12.08   0.000    -1.067404   -.7693532
-------------------+----------------------------------------------------------------
gas                |
             _cons |  -.2106324   .0645314    -3.26   0.001    -.3371116   -.0841532
-------------------+----------------------------------------------------------------
gasoline           |  (base alternative)
-------------------+----------------------------------------------------------------
hybrid             |
             _cons |  -.1594116   .0633919    -2.51   0.012    -.2836575   -.0351658
-------------------+----------------------------------------------------------------
hydrogen           |
             _cons |   -.321559   .0658271    -4.88   0.000    -.4505778   -.1925402
------------------------------------------------------------------------------------
```

Example 1: Energy sources and propulsion technologies in vehicles (VII)

```
asmprobit choice price_100000 motorpower_1000 fuelcosts_100 CO2emissions_1000 servicestation_100, case(choiceset)
alternatives(alternatives) correlation(independent) stddev(homoskedastic) base(gasoline) intpoints(50) robust

Alternative-specific multinomial probit        Number of obs      =      25116
Case variable: choiceset                       Number of cases    =       3588

Alternative variable: alternatives             Alts per case: min =          7
                                                              avg =        7.0
                                                              max =          7

Integration sequence:            Hammersley
Integration points:                      50       Wald chi2(5)    =    1049.43
Log simulated-pseudolikelihood =  -6127.711       Prob > chi2     =     0.0000

                                    (Std. Err. adjusted for clustering on choiceset)
------------------------------------------------------------------------------------
                   |               Robust
            choice |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------------+----------------------------------------------------------------
alternatives       |
      price_100000 |  -2.278243   .2494233    -9.13   0.000    -2.767104   -1.789383
   motorpower_1000 |   3.793377   .4130764     9.18   0.000     2.983762    4.602991
     fuelcosts_100 |  -4.659235   .2046631   -22.77   0.000    -5.060367   -4.258103
 CO2emissions_1000 |   -2.51397   .1756331   -14.31   0.000    -2.858204   -2.169735
servicestation_100 |   .7763197   .0389192    19.95   0.000     .7000395    .8525998
-------------------+----------------------------------------------------------------
biofuel            |
             _cons |  -.3960761   .0453435    -8.74   0.000    -.4849479   -.3072044
-------------------+----------------------------------------------------------------
diesel             |
             _cons |   .0601152   .0374664     1.60   0.109    -.0133175    .1335479
-------------------+----------------------------------------------------------------
electric           |
             _cons |  -.5842113   .0476469   -12.26   0.000    -.6775975   -.4908252
-------------------+----------------------------------------------------------------
gas                |
             _cons |  -.1360489   .0421063    -3.23   0.001    -.2185757   -.0535221
-------------------+----------------------------------------------------------------
gasoline           |  (base alternative)
-------------------+----------------------------------------------------------------
hybrid             |
             _cons |  -.1103021   .0416094    -2.65   0.008    -.1918551   -.0287492
-------------------+----------------------------------------------------------------
hydrogen           |
             _cons |  -.2024039   .0430118    -4.71   0.000    -.2867055   -.1181023
------------------------------------------------------------------------------------
```

Example 1: Energy sources and propulsion technologies in vehicles (VIII)

```
asclogit choice price_decimal motorpower_decimal fuelcosts_100 CO2emissions_1000 servicestation_100, case(choiceset)
alternatives(alternatives) base(gasoline) robust

Alternative-specific conditional logit         Number of obs      =      25116
Case variable: id                              Number of cases    =       3588

Alternative variable: alternatives             Alts per case: min =          7
                                                              avg =        7.0
                                                              max =          7

                                                  Wald chi2(5)    =    1063.69
Log pseudolikelihood =  -6141.756                 Prob > chi2     =     0.0000

                                          (Std. Err. adjusted for clustering on id)
------------------------------------------------------------------------------------
                   |               Robust
            choice |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------------+----------------------------------------------------------------
alternatives       |
     price_decimal | -.9513986    .088458   -10.76   0.000    -1.124773   -.7780242
motorpower_decimal |  .4919794   .1085127     4.53   0.000     .2792985    .7046603
     fuelcosts_100 | -7.571348   .3293427   -22.99   0.000    -8.216848   -6.925848
 CO2emissions_1000 | -4.115056   .2810027   -14.64   0.000    -4.665811   -3.564301
servicestation_100 |  1.223275    .060173    20.33   0.000     1.105338    1.341212
-------------------+----------------------------------------------------------------
biofuel            |
             _cons | -.6287628   .0705405    -8.91   0.000    -.7670196    -.490506
-------------------+----------------------------------------------------------------
diesel             |
             _cons |   .089125   .0548691     1.62   0.104    -.0184165    .1966664
-------------------+----------------------------------------------------------------
electric           |
             _cons | -.9209775     .07597   -12.12   0.000    -1.069876   -.7720791
-------------------+----------------------------------------------------------------
gas                |
             _cons | -.2060089     .06458    -3.19   0.001    -.3325834   -.0794344
-------------------+----------------------------------------------------------------
gasoline           |  (base alternative)
-------------------+----------------------------------------------------------------
hybrid             |
             _cons | -.1581784   .0633614    -2.50   0.013    -.2823643   -.0339924
-------------------+----------------------------------------------------------------
hydrogen           |
             _cons | -.3186239     .06567    -4.85   0.000    -.4473347   -.1899131
------------------------------------------------------------------------------------
```

Example 1: Energy sources and propulsion technologies in vehicles (IX)

```
asmprobit choice price_decimal motorpower_decimal fuelcosts_100 CO2emissions_1000 servicestation_100, case(choiceset)
alternatives(alternatives) correlation(independent) stddev(homoskedastic) base(gasoline) intpoints(50) robust

Alternative-specific multinomial probit        Number of obs      =      25116
Case variable: id                              Number of cases    =       3588

Alternative variable: alternatives             Alts per case: min =          7
                                                              avg =        7.0
                                                              max =          7

Integration sequence:            Hammersley
Integration points:                      50       Wald chi2(5)    =    1028.44
Log simulated-pseudolikelihood = -6154.4005       Prob > chi2     =     0.0000

                                    (Std. Err. adjusted for clustering on id)
------------------------------------------------------------------------------
                   |               Robust
            choice |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------------+----------------------------------------------------------------
alternatives       |
     price_decimal |  -.5823166   .0557268   -10.45   0.000    -.6915392   -.4730941
motorpower_decimal |   .3102772     .07013     4.42   0.000      .172825    .4477295
     fuelcosts_100 |   -4.68001   .1982548   -23.61   0.000    -5.068583   -4.291438
 CO2emissions_1000 |  -2.503315   .1684615   -14.86   0.000    -2.833494   -2.173137
servicestation_100 |   .7718634   .0383062    20.15   0.000     .6967846    .8469422
-------------------+----------------------------------------------------------------
biofuel            |
             _cons |  -.3974431   .0454821    -8.74   0.000    -.4865863   -.3082999
-------------------+----------------------------------------------------------------
diesel             |
             _cons |   .0598091   .0374048     1.60   0.110    -.0135029    .1331211
-------------------+----------------------------------------------------------------
electric           |
             _cons |  -.5847496   .0474987   -12.31   0.000    -.6778453   -.4916539
-------------------+----------------------------------------------------------------
gas                |
             _cons |  -.1328942   .0422736    -3.14   0.002     -.215749   -.0500394
-------------------+----------------------------------------------------------------
gasoline           |  (base alternative)
-------------------+----------------------------------------------------------------
hybrid             |
             _cons |   -.109475   .0417199    -2.62   0.009    -.1912445   -.0277056
-------------------+----------------------------------------------------------------
hydrogen           |
             _cons |  -.2019579   .0408415    -4.94   0.000    -.2820058     -.12191
------------------------------------------------------------------------------
```

Example 1: Energy sources and propulsion technologies in vehicles (X)

```
asclogit choice price_decimal motorpower_decimal fuelcosts_100 CO2emissions_1000 servicestation_100,
case(choiceset) alternatives(alternatives) casevars(age_100 male environment_friendly) base(gasoline)

Alternative-specific conditional logit         Number of obs      =      25116
Case variable: id                              Number of cases    =       3588

Alternative variable: alternatives             Alts per case: min =          7
                                                              avg =        7.0
                                                              max =          7

                                                  Wald chi2(23)   =    1304.16
Log likelihood = -6060.8399                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------
              choice |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------------+--------------------------------------------------------
alternatives         |
       price_decimal |  -.9487371    .088781   -10.69   0.000    -1.122745   -.7747296
  motorpower_decimal |   .4837028   .1107786     4.37   0.000     .2665806    .7008249
       fuelcosts_100 |  -7.631049   .3260682   -23.40   0.000    -8.270131   -6.991967
   CO2emissions_1000 |  -4.175772   .2779365   -15.02   0.000    -4.720518   -3.631027
  servicestation_100 |   1.234832   .0610008    20.24   0.000     1.115273    1.354392
---------------------+--------------------------------------------------------
biofuel              |
             age_100 |  -2.562941   .4518629    -5.67   0.000    -3.448576   -1.677306
                male |   .1996596   .1465551     1.36   0.173    -.0875832    .4869024
environment_friendly |   .6928068   .1451092     4.77   0.000     .4083979    .9772156
               _cons |   .1747254   .2188197     0.80   0.425    -.2541534    .6036041
---------------------+--------------------------------------------------------
diesel               |
             age_100 |   -1.59606   .3667013    -4.35   0.000    -2.314781   -.8773383
                male |   .5861857   .1290669     4.54   0.000     .3332191    .8391523
environment_friendly |  -.0562276   .1284784    -0.44   0.662    -.3080407    .1955854
               _cons |   .4156353   .1861066     2.23   0.026     .0508731    .7803974
---------------------+--------------------------------------------------------
```

Example 1: Energy sources and propulsion technologies in vehicles (XI)

```
---------------------+----------------------------------------------------------------
electric             |
             age_100 |  -3.748376   .4972008    -7.54   0.000    -4.722872   -2.773881
                male |   .3511305   .1605061     2.19   0.029     .0365443    .6657167
environment_friendly |   .6176549    .159052     3.88   0.000     .3059188    .9293911
               _cons |   .3139058   .2351709     1.33   0.182    -.1470208    .7748323
---------------------+----------------------------------------------------------------
gas                  |
             age_100 |  -3.133422   .4372221    -7.17   0.000    -3.990361   -2.276482
                male |   .5779072   .1487424     3.89   0.000     .2863774    .8694371
environment_friendly |   .2334947   .1478441     1.58   0.114    -.0562743    .5232637
               _cons |   .7257773   .2116237     3.43   0.001     .3110025    1.140552
---------------------+----------------------------------------------------------------
gasoline             |  (base alternative)
---------------------+----------------------------------------------------------------
hybrid               |
             age_100 |  -1.882713   .4233082    -4.45   0.000    -2.712382   -1.053044
                male |   .4848538   .1462962     3.31   0.001     .1981186     .771589
environment_friendly |   .3669965   .1419393     2.59   0.010     .0888005    .6451925
               _cons |   .2569248   .2099813     1.22   0.221    -.1546309    .6684805
---------------------+----------------------------------------------------------------
hydrogen             |
             age_100 |  -2.868189   .4129016    -6.95   0.000    -3.677461   -2.058917
                male |   .6137354   .1410775     4.35   0.000     .3372286    .8902422
environment_friendly |   .6222545   .1352587     4.60   0.000     .3571524    .8873567
               _cons |    .343097   .2041127     1.68   0.093    -.0569565    .7431505
--------------------------------------------------------------------------------------

estimates store allalt
```

Example 1: Energy sources and propulsion technologies in vehicles (XII)

```
asclogit choice price_decimal motorpower_decimal fuelcosts_100 CO2emissions_1000 servicestation_100 if
energysource != 3 & energysource != 4, case(choiceset) alternatives(alternatives) casevars(age_100 male
environment_friendly) base(gasoline)
```

```
Alternative-specific conditional logit         Number of obs      =      13785
Case variable: id                              Number of cases    =       2757

Alternative variable: alternatives             Alts per case: min =          5
                                                              avg =        5.0
                                                              max =          5

                                                  Wald chi2(17)   =     880.49
Log likelihood = -3785.0231                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------------
              choice |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------------+--------------------------------------------------------------
alternatives         |
       price_decimal |  -.9736709   .1064197    -9.15   0.000     -1.18225   -.7650922
  motorpower_decimal |   .4152834   .1334683     3.11   0.002     .1536904    .6768764
       fuelcosts_100 |   -7.54238   .3851393   -19.58   0.000    -8.297239   -6.787521
   CO2emissions_1000 |  -4.167421   .3342439   -12.47   0.000    -4.822527   -3.512315
  servicestation_100 |   1.233177   .0779781    15.81   0.000     1.080343    1.386011
---------------------+--------------------------------------------------------------
diesel               |
             age_100 |  -1.477723   .3628389    -4.07   0.000    -2.188874   -.7665715
                male |   .5868516   .1302823     4.50   0.000      .331503    .8422001
environment_friendly |  -.0537079    .130038    -0.41   0.680    -.3085778    .2011619
               _cons |   .3530199   .1860886     1.90   0.058     -.011707    .7177468
---------------------+--------------------------------------------------------------
electric             |
             age_100 |  -3.555125   .4921031    -7.22   0.000    -4.519629   -2.590621
                male |   .3199779   .1621268     1.97   0.048     .0022152    .6377405
environment_friendly |   .5792934   .1611062     3.60   0.000      .263531    .8950558
               _cons |   .2431727   .2361371     1.03   0.303    -.2196475    .7059929
---------------------+--------------------------------------------------------------
gasoline             |  (base alternative)
---------------------+--------------------------------------------------------------
hybrid               |
             age_100 |  -1.672995   .4181398    -4.00   0.000    -2.492534   -.8534563
                male |   .4580474   .1477446     3.10   0.002     .1684732    .7476216
environment_friendly |   .3534737   .1434089     2.46   0.014     .0723975    .6345499
               _cons |   .1762681   .2101444     0.84   0.402    -.2356075    .5881436
---------------------+--------------------------------------------------------------
hydrogen             |
             age_100 |  -2.662978   .4078856    -6.53   0.000    -3.462419   -1.863536
                male |   .5663865   .1427493     3.97   0.000     .2866029      .84617
environment_friendly |   .5759117   .1369431     4.21   0.000      .307508    .8443153
               _cons |   .2943916   .2056368     1.43   0.152    -.1086491    .6974322
------------------------------------------------------------------------------------
```

Example 1: Energy sources and propulsion technologies in vehicles (XIII)

```
hausman allalt, alleqs

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     allalt         .          Difference          S.E.
-------------+----------------------------------------------------------------
alternatives |
price_deci~l |   -.9487371    -.9736709        .0249337               .
motorpower~l |    .4837028     .4152834        .0684193               .
fuelcost~100 |   -7.631049     -7.54238       -.0886684               .
CO2emis~1000 |   -4.175772    -4.167421       -.0083514               .
services~100 |    1.234832     1.233177        .0016556               .
-------------+----------------------------------------------------------------
diesel       |
     age_100 |    -1.59606    -1.477723       -.1183369        .0530827
        male |    .5861857     .5868516       -.0006659               .
environmen~y |   -.0562276    -.0537079       -.0025197               .
-------------+----------------------------------------------------------------
electric     |
     age_100 |   -3.748376    -3.555125       -.1932514        .0710159
        male |    .3511305     .3199779        .0311526               .
environmen~y |    .6176549     .5792934        .0383615               .
-------------+----------------------------------------------------------------
hybrid       |
     age_100 |   -1.882713    -1.672995        -.209718        .0659466
        male |    .4848538     .4580474        .0268064               .
environmen~y |    .3669965     .3534737        .0135228               .
-------------+----------------------------------------------------------------
hydrogen     |
     age_100 |   -2.868189    -2.662978       -.2052112        .0641641
        male |    .6137354     .5663865        .0473489               .
environmen~y |    .6222545     .5759117        .0463429               .
------------------------------------------------------------------------------
                        b = consistent under Ho and Ha; obtained from asclogit
         B = inconsistent under Ha, efficient under Ho; obtained from asclogit

    Test:  Ho:  difference in coefficients not systematic

                 chi2(17) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       61.10
                Prob>chi2 =      0.0000
                (V_b-V_B is not positive definite)
```

Example 1: Energy sources and propulsion technologies in vehicles (XIV)

```
mixlogit choice price_decimal diesel gas biofuel hydrogen hybrid electric,
group(choiceset) id(individuals) rand(motorpower_decimal fuelcosts_100
CO2emissions_1000 servicestation_100) nrep(100) robust

Mixed logit model                                 Number of obs   =      25116
                                                  Wald chi2(11)   =     704.67
Log likelihood =  -5893.353                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------------
                   |               Robust
            choice |      Coef.   Std. Err.       z    P>|z|     [95% Conf. Interval]
-------------------+----------------------------------------------------------------
Mean               |
     price_decimal |  -1.152931   .1197803    -9.63   0.000    -1.387696    -.918166
            diesel |    .114394   .0970001     1.18   0.238    -.0757227    .3045108
               gas |  -.2601992    .109164    -2.38   0.017    -.4741566   -.0462417
           biofuel |  -.8163822   .1087872    -7.50   0.000    -1.029601   -.6031632
          hydrogen |  -.4452178   .1117935    -3.98   0.000     -.664329   -.2261066
            hybrid |  -.2064548   .1038973    -1.99   0.047    -.4100897   -.0028198
          electric |  -1.149051   .1149146   -10.00   0.000    -1.374279   -.9238223
motorpower_decimal |   .5606585   .1533231     3.66   0.000     .2601507    .8611664
     fuelcosts_100 |  -10.38913   .6569293   -15.81   0.000    -11.67669    -9.10157
 CO2emissions_1000 |  -5.072652    .407195   -12.46   0.000    -5.870739   -4.274564
servicestation_100 |   1.515371   .1045673    14.49   0.000     1.310423    1.720319
-------------------+----------------------------------------------------------------
SD                 |
motorpower_decimal |   1.657275   .2688995     6.16   0.000     1.130241    2.184308
     fuelcosts_100 |   9.506411   .7197837    13.21   0.000     8.095661    10.91716
 CO2emissions_1000 |   6.318972   .4597666    13.74   0.000     5.417846    7.220098
servicestation_100 |   1.683082   .1190606    14.14   0.000     1.449728    1.916437
------------------------------------------------------------------------------------
```

Example 1: Energy sources and propulsion technologies in vehicles (XV)

```
mixlogit choice price_decimal diesel gas biofuel hydrogen hybrid electric age_diesel age_gas
age_biofuel age_hydrogen age_hybrid age_electric male_diesel male_gas male_biofuel
male_hydrogen male_hybrid male_electric env_diesel env_gas env_biofuel env_hydrogen env_hybrid
env_electric, group(choiceset) id(individuals) rand(motorpower_decimal fuelcosts_100
CO2emissions_1000 servicestation_100) nrep(5)
```

```
Mixed logit model                                 Number of obs   =      25116
                                                  LR chi2(4)      =     252.43
Log likelihood = -5934.6262                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------------
            choice |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------------+----------------------------------------------------------------
Mean               |
     price_decimal |  -1.032654   .0943062   -10.95   0.000    -1.217491    -.847817
            diesel |   .4778174   .1920106     2.49   0.013     .1014835    .8541512
               gas |    .861209   .2192962     3.93   0.000     .4313963    1.291022
           biofuel |   .2782128    .232375     1.20   0.231    -.1772337    .7336594
          hydrogen |   .3371377   .2186315     1.54   0.123    -.0913721    .7656476
            hybrid |   .3603566   .2167583     1.66   0.096    -.0644819     .785195
          electric |   .3766095   .2519047     1.50   0.135    -.1171147    .8703337
        age_diesel |  -.0174023   .0037944    -4.59   0.000    -.0248391   -.0099655
           age_gas |  -.0355684   .0045697    -7.78   0.000    -.0445249    -.026612
       age_biofuel |  -.0305214   .0048031    -6.35   0.000    -.0399353   -.0211076
      age_hydrogen |  -.0314858   .0044428    -7.09   0.000    -.0401934   -.0227782
        age_hybrid |  -.0215847   .0043804    -4.93   0.000    -.0301701   -.0129992
      age_electric |  -.0419787    .005316    -7.90   0.000     -.052398   -.0315595
       male_diesel |   .6239399   .1338339     4.66   0.000     .3616304    .8862495
          male_gas |    .622389   .1549903     4.02   0.000     .3186137    .9261644
      male_biofuel |   .2201399   .1569898     1.40   0.161    -.0875544    .5278342
     male_hydrogen |   .7132127     .15203     4.69   0.000     .4152394    1.011186
       male_hybrid |   .5021938   .1522135     3.30   0.001     .2038609    .8005267
     male_electric |   .3860522   .1712318     2.25   0.024     .0504441    .7216603
```

Example 1: Energy sources and propulsion technologies in vehicles (XVI)

```
-------------------+----------------------------------------------------------------
        env_diesel |  -.0581815   .1330155    -0.44   0.662    -.3188872    .2025241
           env_gas |   .2444517   .1536347     1.59   0.112    -.0566668    .5455703
       env_biofuel |   .7172262   .1547238     4.64   0.000     .4139732    1.020479
      env_hydrogen |   .6128832   .1460365     4.20   0.000     .3266569    .8991096
        env_hybrid |   .3709122   .1474779     2.52   0.012     .0818609    .6599636
      env_electric |   .6119939   .1695082     3.61   0.000     .2797639    .9442239
 motorpower_decimal |   .5443154   .1178504     4.62   0.000     .3133329    .7752978
     fuelcosts_100 |  -8.656736   .4241358   -20.41   0.000    -9.488026   -7.825445
  CO2emissions_1000 |  -4.697025   .3377086   -13.91   0.000    -5.358922   -4.035129
 servicestation_100 |   1.316358   .0745108    17.67   0.000     1.170319    1.462396
-------------------+----------------------------------------------------------------
SD                 |
 motorpower_decimal |   .0233069   .3343648     0.07   0.944    -.6320361    .6786499
     fuelcosts_100 |  -6.080686   .6500041    -9.35   0.000    -7.354671   -4.806702
  CO2emissions_1000 |   4.922441   .4547904    10.82   0.000     4.031068    5.813814
 servicestation_100 |   1.158471   .1103848    10.49   0.000      .942121    1.374821
------------------------------------------------------------------------------------

estimates store mixlogit

asclogit choice price_decimal motorpower_decimal fuelcosts_100 CO2emissions_1000
servicestation_100, case(choiceset) alternatives(alternatives) casevars(age_100 male
environment_friendly) base(gasoline)

lrtest mixlogit, force

Likelihood-ratio test                                 LR chi2(4)  =    252.43
(Assumption: . nested in mixlogit)                    Prob > chi2 =    0.0000
```

Example 1: Energy sources and propulsion technologies in vehicles (XVII)

Estimated WTP (based on the customized purchase price in decimals) for reduced CO_2 emissions (in 1000 gram per kilometer) and for service station availability (in decimals of stations with respective fuel):

- Page 33: Multinomial logit model with only alternative specific attributes
  - $\widehat{WTP}_{CO2}$ = -4.325 [=-(-4.115056/-0.9513986)], i.e. the estimated average WTP is approximately 0.4325 percentage points with respect to the purchase price for a reduction of the CO_2 emissions by 1 gram (which is 0.004325·20725 = 89.64 Euro due to the average purchase price of 20725 Euro)
  - $\widehat{WTP}_{station}$ = 1.286 [=-(1.223275/-0.9513986)], i.e. the estimated average WTP is approximately 1.286 percentage points with respect to the purchase price for an increase of the service station availability by 1 percentage point (which is 0.01286·20725 = 266.52 Euro)
- Page 34: Independent multinomial probit model with only alternative specific attributes
  - $\widehat{WTP}_{CO2}$ = -4.299 or 0.004299·20725 = 89.10 Euro
  - $\widehat{WTP}_{station}$ = 1.326 or 0.01326·20725 = 274.81 Euro

---

Example 1: Energy sources and propulsion technologies in vehicles (XVIII)

- Page 35: Full multinomial logit model
  - $\widehat{WTP}_{CO2}$ = -4.401 or 0.004401·20725 = 91.21 Euro
  - $\widehat{WTP}_{station}$ = 1.302 or 0.01302·20725 = 269.84 Euro
- Page 39/40/41: Mixed logit models with only alternative specific attributes and full mixed logit model
  - $\widehat{WTP}_{CO2}$ = -4.400 (91.19 Euro) and -4.548 (94.27 Euro)
  - $\widehat{WTP}_{station}$ = 1.314 (272.40 Euro) and 1.127 (264.19 Euro)

Estimated WTP (based on the purchase price divided by 100000) for reduced CO_2 emissions (in 1000 gram per kilometer) and for service station availability (in decimals of stations with respective fuel):

- Page 31: Multinomial logit model with only alternative specific attributes
  - $\widehat{WTP}_{CO2}$ = -1.118 [=-(-4.124038/-3.689678)], i.e. the estimated average WTP is approximately 111.8 Euro for a reduction of the CO_2 emissions by 1 gram
  - $\widehat{WTP}_{station}$ = 0.334 [=-(1.232526/-3.689678)], i.e. the estimated average WTP is approximately 334 Euro for an increase of the service station availability by 1 percentage point

---

Example 1: Energy sources and propulsion technologies in vehicles (XIX)

Finally, the ML estimation of a latent class logit model with two classes and with alternative specific attributes and alternative specific constants is considered (age_100, male, and environment_friendly are included in the membership model):

```
lclogit choice price_decimal motorpower_decimal fuelcosts_100 CO2emissions_1000
servicestation_100 diesel gas biofuel hydrogen hybrid electric, membership(age_100 male
environment_friendly) group(choiceset) id(individuals) nclasses(2) seed(2)
```

```
Latent class model with 2 latent classes

Choice model parameters and average classs shares
-------------------------------
    Variable |  Class1   Class2
-------------+-----------------
price_deci~l |  -1.159   -0.281
motorpower~l |   0.575    0.104
fuelcost~100 |  -9.333   -3.465
CO2emis~1000 |  -4.892   -1.115
services~100 |   1.344    0.927
      diesel |   0.224   -0.054
         gas |   0.517   -2.422
     biofuel |   0.025   -2.599
    hydrogen |   0.395   -3.551
      hybrid |   0.556   -2.282
    electric |  -0.227   -3.772
-------------+-----------------
 Class Share |   0.780    0.220
-------------------------------
```

Example 1: Energy sources and propulsion technologies in vehicles (XX)

Class membership model parameters : Class2 = Reference class

Variable	Class1	Class2
age_100	-4.964	0.000
male	0.092	0.000
environmen~y	0.568	0.000
_cons	3.386	0.000

lclogitml

Latent class model with 2 latent classes

choice	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
choice1						
price_decimal	-1.158792	.1059631	-10.94	0.000	-1.366476	-.9511084
motorpower_decimal	.5748627	.1291412	4.45	0.000	.3217506	.8279747
fuelcosts_100	-9.333472	.4100292	-22.76	0.000	-10.13711	-8.52983
CO2emissions_1000	-4.892207	.3204516	-15.27	0.000	-5.52028	-4.264133
servicestation_100	1.344335	.0688776	19.52	0.000	1.209338	1.479333
diesel	.2236502	.085048	2.63	0.009	.0569593	.3903412
gas	.5170894	.0889466	5.81	0.000	.3427573	.6914215
biofuel	.0246264	.0932984	0.26	0.792	-.1582352	.2074879
hydrogen	.3948669	.0897299	4.40	0.000	.2189996	.5707341
hybrid	.5555942	.0877449	6.33	0.000	.3836174	.7275711
electric	-.2266319	.0985213	-2.30	0.021	-.41973	-.0335337

Example 1: Energy sources and propulsion technologies in vehicles (XXI)

choice2						
price_decimal	-.2806668	.2366267	-1.19	0.236	-.7444467	.1831131
motorpower_decimal	.1042983	.3175214	0.33	0.743	-.5180322	.7266288
fuelcosts_100	-3.465026	.7931911	-4.37	0.000	-5.019652	-1.9104
CO2emissions_1000	-1.115138	.8750632	-1.27	0.203	-2.83023	.5999548
servicestation_100	.9266868	.2236876	4.14	0.000	.4882671	1.365106
diesel	-.0540939	.0877225	-0.62	0.537	-.2260269	.1178391
gas	-2.421538	.2684773	-9.02	0.000	-2.947744	-1.895332
biofuel	-2.598783	.2716144	-9.57	0.000	-3.131138	-2.066429
hydrogen	-3.551382	.480541	-7.39	0.000	-4.493225	-2.609539
hybrid	-2.28184	.2755736	-8.28	0.000	-2.821954	-1.741726
electric	-3.771694	.4938859	-7.64	0.000	-4.739692	-2.803695
share1						
age_100	-4.964043	.6984837	-7.11	0.000	-6.333046	-3.59504
male	.0923229	.2666069	0.35	0.729	-.4302169	.6148627
environment_friendly	.5684257	.2510127	2.26	0.024	.0764499	1.060402
_cons	3.385687	.4091422	8.28	0.000	2.583783	4.187591

```
test price_decimal

 ( 1)  [choice1]price_decimal = 0
 ( 2)  [choice2]price_decimal = 0

           chi2(  2) =  124.02
         Prob > chi2 =    0.0000

test environment_friendly

 ( 1)  [share1]environment_friendly = 0

           chi2(  1) =    5.13
         Prob > chi2 =    0.0235
```

Example 1: Energy sources and propulsion technologies in vehicles (XXII)

Interpretation:

- Age has a significantly negative effect and environmental awareness has a significantly positive effect on the membership in class 1, whereas gender has no significant effect on the class membership
- The members of class 2 have a strong significant preference for gasoline vehicles compared to alternative energy sources and propulsion technologies
- The estimated effects of the alternative specific attributes for the members of class 1 are similar to the previously estimated effects
- In contrast, only the effects of fuel costs and service station availability are significant for the members of class 2
- Therefore, the estimation of WTP is only useful for the members of class 1, e.g. for reduced CO_2 emissions (in 1000 gram per kilometer) and for service station availability (in decimals of stations with respective fuel):
  - $\widehat{WTP}_{CO2}$ = -4.222 [=-(-4.892207/-1.158792)] or 87.50 Euro
  - $\widehat{WTP}_{station}$ = 1.160 [=-(1.344335/-1.158792)] or 240.43 Euro

---

Example 2: Choice among fixed-interest investment products (I)

In Gutsche and Ziegler (2016, discussion paper), two unlabeled SCE (based on “Balanced Overlap” designs for which 50 different versions of randomized choice sets were created for each SCE and assigned to the respondents) are examined, which comprised choices among several investment products:

- While one SCE referred to the choice among four different equity funds (the data are discussed and examined in the tutorial), the other SCE referred to the choice among four alternative fixed-interest investment products with an investment horizon of three years
- All data stem from a computer-based survey during December 2013 and January 2014, carried out in cooperation with the German market research institute GfK SE, which drew a sample from its internal representative (in terms of age, gender, and place of origin) online panel
- 1001 respondents from the population of financial decision makers in Germany with a minimum of investment experiences (i.e. the respondents must have at least a savings account) participated in the survey and thus in this SCE
- The SCE was based on six choice sets and comprised four attributes, i.e. provider, annual nominal interest rate, sustainability criteria, and transparency logo

Example 2: Choice among fixed-interest investment products (II)

Attribute levels:

- Provider (dummy variables): Big bank (base variable), municipal savings bank, co-operative bank, direct bank, sustainability bank
- Annual nominal interest rate: 1.30%, 1.50%, 1.70%, 1.90%, 2.10%
- Sustainability criteria (dummy variables): No consideration (base variable), consideration without sustainability certificate, consideration with sustainability certificate (summarized in the variable sustainability)
- Transparency logo (dummy variables): No transparency logo (base variable), transparency logo issued by an NGO, transparency logo issued by the state (summarized in the variable transparency)

Individual characteristics:

- Social values and norms (dummy variables): Warm glow, expectations from the social environment, membership to an environmental organization, affinity with left or right-wings parties
- Socio-demographic variables (dummy variables with the exception of age, which is measured in years): Female, high education, living together or married, Western Germany

Example 2: Choice among fixed-interest investment products (III)

Typical choice set:

Please indicate which of the following four investment products you would most likely purchase.				
Attribute	Three-year fixed-interest investment product A	Three-year fixed-interest investment product B	Three-year fixed-interest investment product C	Three-year fixed-interest investment product D
Provider	Direct bank	Direct bank	Big bank	Municipal savings bank
Yearly nominal interest rate	1.30%	1.70%	1.50%	1.30%
Sustainability criteria	No consideration	Consideration with certificate	Consideration without certificate	No consideration
Transparency logo	No transparency logo	Transparency logo issued by an NGO	Transparency logo issued by the state	No transparency logo
	□	□	□	□

Example 2: Choice among fixed-interest investment products (IV)

The following estimations are considered:

- ML estimation of the conditional logit model with robustly estimated variances, but without including alternative specific constants (since it is an unlabeled SCE) and SML estimation of the corresponding mixed logit model
- Simulated likelihood ratio test for the validity of the conditional logit model
- SML estimation of the full mixed logit model including the individual characteristics as interaction terms with sustainability (based on n = 708 respondents due to missing values for the individual characteristics)
- (Approximate) replications of the results in Table 10 and Table 11 of the paper (results in the paper are based on Stata 12): ML estimation of latent class logit models with two and three classes with the alternative specific attributes and the alternative specific constants and with five iterations in the additional ML estimation with the Newton-Raphson alg-rithm, whereby the individual characteristics are included in the membership model (also based on n = 708 respondents)
- Estimation of WTP for sustainability criteria, respectively (i.e. the estimated average value of percentage points with respect to the yearly nominal interest rate, the persons are willing to sacrifice for sustainability criteria)

Example 2: Choice among fixed-interest investment products (V)

```
asclogit choice InterestRate Sustainability Transparency MunicipalBank CooperativeBank
DirectBank SustBank, case(gid) alternatives(alternative) noconstant robust

Alternative-specific conditional logit         Number of obs      =      24024
Case variable: gid                             Number of cases    =       6006

Alternative variable: alternative              Alts per case: min =          4
                                                              avg =        4.0
                                                              max =          4

                                                  Wald chi2(7)    =    2465.47
Log pseudolikelihood = -6471.0994                 Prob > chi2     =     0.0000

                                       (Std. Err. adjusted for clustering on gid)
--------------------------------------------------------------------------------
                |               Robust
         choice |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
----------------+---------------------------------------------------------------
alternative     |
   InterestRate |   3.079548   .0682445    45.13   0.000     2.945791    3.213305
 Sustainability |   .5999934   .0361356    16.60   0.000      .529169    .6708178
   Transparency |   .6910839   .0354122    19.52   0.000     .6216772    .7604906
  MunicipalBank |   .5325289   .0512667    10.39   0.000      .432048    .6330098
CooperativeBank |   .5008757   .0505109     9.92   0.000      .401876    .5998753
     DirectBank |   .1375595   .0508649     2.70   0.007     .0378662    .2372528
       SustBank |   .3190195   .0545459     5.85   0.000     .2121115    .4259274
--------------------------------------------------------------------------------

estimates store condlogit
```

$\rightarrow \widehat{WTP}_{sust}$ = -0.195 [=-(0.5999934/3.079548)]

Example 2: Choice among fixed-interest investment products (VI)

```
mixlogit choice InterestRate, group(gid) id(id) rand(Sustainability Transparency MunicipalBank
CooperativeBank DirectBank SustBank) nrep(10) robust

Mixed logit model                                 Number of obs   =      24024
                                                  Wald chi2(7)    =    1042.91
Log likelihood = -6266.5199                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------
                |               Robust
         choice |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
----------------+-------------------------------------------------------------
Mean            |
   InterestRate |   3.535709   .1235619    28.61   0.000     3.293532    3.777886
 Sustainability |   .7223758   .0521778    13.84   0.000     .6201091    .8246425
   Transparency |   .8350265   .0559949    14.91   0.000     .7252786    .9447744
  MunicipalBank |   .5144328   .0695416     7.40   0.000     .3781338    .6507318
CooperativeBank |   .5070607   .0656249     7.73   0.000     .3784382    .6356832
     DirectBank |   .1352623   .0580148     2.33   0.020     .0215553    .2489693
       SustBank |    .251023   .0713139     3.52   0.000     .1112502    .3907957
----------------+-------------------------------------------------------------
SD              |
 Sustainability |   .8885514   .0901503     9.86   0.000     .7118601    1.065243
   Transparency |   .6820224   .1363723     5.00   0.000     .4147377    .9493072
  MunicipalBank |   1.057992   .1410059     7.50   0.000     .7816253    1.334358
CooperativeBank |    .692157   .1346609     5.14   0.000     .4282265    .9560875
     DirectBank |  -.1793131   .1130124    -1.59   0.113    -.4008133    .0421872
       SustBank |  -.7008728   .1580349    -4.43   0.000    -1.010616   -.3911302
------------------------------------------------------------------------------

estimates store mixedlogit
```

→ $\widehat{WTP}_{sust}$ = -0.204 [=-(0.7223758/3.535709)]

Example 2: Choice among fixed-interest investment products (VII)

```
lrtest mixedlogit condlogit, force

Likelihood-ratio test                               LR chi2(6)  =    409.16
(Assumption: condlogit nested in mixedlogit)        Prob > chi2 =    0.0000
```

Replication of results in Table 6 of the paper (with R = 1000 Halton draws):

```
mixlogit choice InterestRate, group(gid) id(id) rand(Sustainability Transparency MunicipalBank
CooperativeBank DirectBank SustBank) nrep(1000) robust

Mixed logit model                                     Number of obs = 24,024
                                                      Wald chi2(7)  = 869.85
Log likelihood = -6145.605                            Prob > chi2   = 0.0000

--------------------------------------------------------------------------------
                |               Robust
         choice | Coefficient  std. err.      z    P>|z|     [95% conf. interval]
----------------+---------------------------------------------------------------
Mean            |
   InterestRate |   3.973192   .1517999    26.17   0.000      3.67567    4.270715
 Sustainability |   .8328645   .0586778    14.19   0.000     .7178581    .9478709
   Transparency |    1.02731   .0620928    16.54   0.000     .9056102    1.149009
  MunicipalBank |   .4871003   .0744113     6.55   0.000     .3412569    .6329437
CooperativeBank |   .5017479   .0711371     7.05   0.000     .3623218    .6411741
     DirectBank |   .1129445   .0629538     1.79   0.073    -.0104425    .2363316
       SustBank |   .2153831   .0764495     2.82   0.005     .0655449    .3652213
----------------+---------------------------------------------------------------
SD              |
 Sustainability |   1.067187   .0738109    14.46   0.000     .9225199    1.211853
   Transparency |   1.052439   .0817108    12.88   0.000     .8922888    1.212589
  MunicipalBank |   1.288292   .1068582    12.06   0.000     1.078853     1.49773
CooperativeBank |   1.069791   .1038642    10.30   0.000     .8662205    1.273361
     DirectBank |   .5094532    .152021     3.35   0.001     .2114976    .8074088
       SustBank |    1.14098    .104213    10.95   0.000     .9367259    1.345233
--------------------------------------------------------------------------------
```

$\rightarrow \widehat{WTP}_{sust}$ = -0.210 [=-(0. 8328645/3.973192)]

Example 2: Choice among fixed-interest investment products (VIII)

```
mixlogit choice InterestRate SustWarmGlow SustExpectEnvironment SustEnvOrganization SustLeftWing SustAge SustFemale
SustHighEducation SustLivingTogether SustWest, group(gid) id(id) rand(Sustainability Transparency MunicipalBank
CooperativeBank DirectBank SustBank) nrep(10) robust

Mixed logit model                                 Number of obs   =      16992
                                                  Wald chi2(16)   =     783.02
Log likelihood = -4342.2057                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------
                     |               Robust
              choice |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------------+--------------------------------------------------------
Mean                 |
        InterestRate |   3.584653   .1500836    23.88   0.000     3.290495    3.878812
        SustWarmGlow |   .7232644   .1209516     5.98   0.000     .4862035    .9603253
SustExpectEnvironment |  -.1086212   .1985252    -0.55   0.584    -.4977235    .2804811
 SustEnvOrganization |   .3547227   .2034193     1.74   0.081    -.0439717    .7534172
        SustLeftWing |    .493711   .1146748     4.31   0.000     .2689526    .7184694
             SustAge |  -.0006806   .0046267    -0.15   0.883    -.0097487    .0083874
          SustFemale |   .0994594   .1138096     0.87   0.382    -.1236034    .3225222
   SustHighEducation |   .1314268   .1206158     1.09   0.276    -.1049758    .3678294
  SustLivingTogether |   .2125078   .1210841     1.76   0.079    -.0248128    .4498283
            SustWest |  -.3499575   .1597018    -2.19   0.028    -.6629673   -.0369477
      Sustainability |   .2970432   .2980038     1.00   0.319    -.2870336    .8811199
        Transparency |   .9263078   .0653271    14.18   0.000     .7982691    1.054346
       MunicipalBank |   .4276778   .0798278     5.36   0.000     .2712182    .5841373
     CooperativeBank |   .5166195   .0804274     6.42   0.000     .3589848    .6742542
          DirectBank |   .1069876   .0692616     1.54   0.122    -.0287626    .2427379
            SustBank |   .2129217   .0840255     2.53   0.011     .0482347    .3776087
---------------------+--------------------------------------------------------
SD                   |
      Sustainability |   .7966505   .0901661     8.84   0.000     .6199282    .9733728
        Transparency |    .759705   .1264612     6.01   0.000     .5118457    1.007564
       MunicipalBank |    .861888   .1400705     6.15   0.000     .5873548    1.136421
     CooperativeBank |    .762845   .1777057     4.29   0.000     .4145483    1.111142
          DirectBank |  -.3154558   .1424412    -2.21   0.027    -.5946354   -.0362763
            SustBank |   .6836249   .1400416     4.88   0.000     .4091483    .9581014
------------------------------------------------------------------------------
```

Example 2: Choice among fixed-interest investment products (IX)

```
lclogit choice InterestRate Sustainability Transparency  MunicipalBank CooperativeBank DirectBank
SustBank, nclasses(2) group(gid) id(id) membership (WarmGlow ExpectEnvironment EnvOrganization LeftWing
Age Female HighEducation LivingTogether West) seed(100)

Latent class model with 2 latent classes

Choice model parameters and average classs shares
-------------------------------
    Variable |  Class1   Class2
-------------+-----------------
InterestRate |  10.734    1.705
Sustainabi~y |   0.672    0.896
Transparency |   0.945    0.869
MunicipalB~k |   0.150    0.685
Cooperativ~k |   0.329    0.670
  DirectBank |  -0.196    0.272
    SustBank |  -0.531    0.488
-------------+-----------------
 Class Share |   0.353    0.647
-------------------------------

Class membership model parameters : Class2 = Reference class
-------------------------------
    Variable |  Class1   Class2
-------------+-----------------
    WarmGlow |  -1.049    0.000
ExpectEnvi~t |  -0.739    0.000
EnvOrganiz~n |  -1.314    0.000
    LeftWing |  -0.601    0.000
         Age |  -0.015    0.000
      Female |  -0.406    0.000
HighEducat~n |   0.412    0.000
LivingToge~r |   0.037    0.000
        West |   0.719    0.000
       _cons |   0.192    0.000
-------------------------------
```

Example 2: Choice among fixed-interest investment products (X)

```
lclogitml, iterate(5)

Latent class model with 2 latent classes
------------------------------------------------------------------------------------
            choice | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------------+----------------------------------------------------------------
choice1            |
      InterestRate |   10.75694   .7324159    14.69   0.000     9.321435    12.19245
    Sustainability |   .6722578   .1396196     4.81   0.000     .3986083    .9459072
      Transparency |   .9447249    .133568     7.07   0.000     .6829364    1.206514
     MunicipalBank |   .1504348   .1795637     0.84   0.402    -.2015036    .5023731
   CooperativeBank |   .3282753   .1778241     1.85   0.065    -.0202536    .6768041
        DirectBank |  -.1959491   .1809963    -1.08   0.279    -.5506953    .1587971
          SustBank |  -.5327292   .2110043    -2.52   0.012    -.9462901   -.1191684
-------------------+----------------------------------------------------------------
choice2            |
      InterestRate |   1.708049   .1109394    15.40   0.000     1.490612    1.925486
    Sustainability |   .8953473   .0546982    16.37   0.000     .7881407    1.002554
      Transparency |   .8688197   .0554445    15.67   0.000     .7601504     .977489
     MunicipalBank |   .6842631    .079772     8.58   0.000     .5279128    .8406134
   CooperativeBank |   .6695327   .0802939     8.34   0.000     .5121595    .8269059
        DirectBank |    .271587   .0817662     3.32   0.001     .1113282    .4318458
          SustBank |   .4873413    .081315     5.99   0.000     .3279669    .6467157
-------------------+----------------------------------------------------------------
share1             |
          WarmGlow |   -1.05113   .2212985    -4.75   0.000    -1.484868   -.6173932
 ExpectEnvironment |  -.7393002   .4323563    -1.71   0.087    -1.586703    .1081025
   EnvOrganization |  -1.315412   .4571276    -2.88   0.004    -2.211366   -.4194584
          LeftWing |  -.6005403   .1992126    -3.01   0.003    -.9909899   -.2100908
               Age |  -.0146788   .0080105    -1.83   0.067     -.030379    .0010214
            Female |  -.4071172   .2041019    -1.99   0.046    -.8071497   -.0070847
     HighEducation |   .4120408   .2115082     1.95   0.051    -.0025077    .8265894
    LivingTogether |   .0377725   .2158235     0.18   0.861    -.3852338    .4607788
              West |   .7193132   .2722074     2.64   0.008     .1857966     1.25283
             _cons |   .1900472   .5197133     0.37   0.715    -.8285722    1.208667
------------------------------------------------------------------------------------
```

Example 2: Choice among fixed-interest investment products (XI)

```
lclogit choice InterestRate Sustainability Transparency MunicipalBank CooperativeBank DirectBank
SustBank, nclasses(3) group(gid) id(id) membership (WarmGlow ExpectEnvironment EnvOrganization LeftWing
Age Female HighEducation LivingTogether West)

Latent class model with 3 latent classes

Choice model parameters and average classs shares
----------------------------------------
    Variable |  Class1   Class2   Class3
-------------+--------------------------
InterestRate |   2.891    0.829   11.226
Sustainabi~y |   1.646    0.197    0.641
Transparency |   1.403    0.411    1.015
MunicipalB~k |   0.564    0.788    0.197
Cooperativ~k |   0.619    0.764    0.262
  DirectBank |   0.509    0.004   -0.217
    SustBank |   0.929   -0.311   -0.605
-------------+--------------------------
 Class Share |   0.413    0.250    0.336
----------------------------------------

Class membership model parameters : Class3 = Reference class
----------------------------------------
    Variable |  Class1   Class2   Class3
-------------+--------------------------
    WarmGlow |   1.723    0.186    0.000
ExpectEnvi~t |   0.445    1.267    0.000
EnvOrganiz~n |   1.471    1.307    0.000
    LeftWing |   0.989    0.179    0.000
         Age |   0.016    0.013    0.000
      Female |   0.383    0.414    0.000
HighEducat~n |  -0.154   -0.691    0.000
LivingToge~r |   0.089   -0.117    0.000
        West |  -0.720   -0.551    0.000
       _cons |  -1.472   -0.410    0.000
----------------------------------------
```

Example 2: Choice among fixed-interest investment products (XII)

```
lclogitml, iterate(5)

Latent class model with 3 latent classes
```

choice	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
choice1						
InterestRate	2.888044	.2001507	14.43	0.000	2.495756	3.280332
Sustainability	1.64287	.119378	13.76	0.000	1.408893	1.876847
Transparency	1.402851	.1011061	13.88	0.000	1.204686	1.601015
MunicipalBank	.5623126	.1391263	4.04	0.000	.2896302	.8349951
CooperativeBank	.6178661	.1370431	4.51	0.000	.3492665	.8864656
DirectBank	.506818	.1384667	3.66	0.000	.2354284	.7782077
SustBank	.9257285	.1411869	6.56	0.000	.6490072	1.20245
choice2						
InterestRate	.8245511	.1869836	4.41	0.000	.45807	1.191032
Sustainability	.195132	.0977312	2.00	0.046	.0035824	.3866816
Transparency	.4081522	.110466	3.69	0.000	.1916427	.6246616
MunicipalBank	.7904712	.1353572	5.84	0.000	.525176	1.055766
CooperativeBank	.7648099	.1329771	5.75	0.000	.5041796	1.02544
DirectBank	.0043657	.1380623	0.03	0.975	-.2662314	.2749627
SustBank	-.3123663	.1782552	-1.75	0.080	-.6617401	.0370076
choice3						
InterestRate	11.22759	.8509539	13.19	0.000	9.559752	12.89543
Sustainability	.6403667	.148278	4.32	0.000	.3497471	.9309863
Transparency	1.014638	.1495712	6.78	0.000	.7214842	1.307793
MunicipalBank	.1967508	.1930677	1.02	0.308	-.1816549	.5751566
CooperativeBank	.2618062	.1877001	1.39	0.163	-.1060792	.6296917
DirectBank	-.2170513	.1917068	-1.13	0.258	-.5927897	.1586872
SustBank	-.6060597	.2181889	-2.78	0.005	-1.033702	-.1784173

Example 2: Choice among fixed-interest investment products (XIII)

share1						
WarmGlow	1.720155	.2615109	6.58	0.000	1.207603	2.232707
ExpectEnvironment	.4472109	.4943392	0.90	0.366	-.5216761	1.416098
EnvOrganization	1.471052	.516438	2.85	0.004	.458852	2.483252
LeftWing	.9858048	.2478956	3.98	0.000	.4999383	1.471671
Age	.0156652	.0097753	1.60	0.109	-.003494	.0348244
Female	.3856622	.2513257	1.53	0.125	-.1069272	.8782516
HighEducation	-.1561053	.2601372	-0.60	0.548	-.6659648	.3537542
LivingTogether	.0877052	.2651321	0.33	0.741	-.4319441	.6073545
West	-.7191945	.316097	-2.28	0.023	-1.338733	-.0996557
_cons	-1.461182	.669632	-2.18	0.029	-2.773636	-.148727
share2						
WarmGlow	.1846444	.2883651	0.64	0.522	-.3805408	.7498295
ExpectEnvironment	1.26877	.48893	2.59	0.009	.3104845	2.227055
EnvOrganization	1.3086	.5255866	2.49	0.013	.2784688	2.33873
LeftWing	.1784874	.2461125	0.73	0.468	-.3038844	.6608591
Age	.0133733	.0097155	1.38	0.169	-.0056687	.0324153
Female	.4121972	.2456358	1.68	0.093	-.0692402	.8936345
HighEducation	-.6900033	.2497134	-2.76	0.006	-1.179433	-.200574
LivingTogether	-.1169762	.2587856	-0.45	0.651	-.6241867	.3902344
West	-.551594	.3171306	-1.74	0.082	-1.173158	.0699706
_cons	-.4158729	.6231495	-0.67	0.505	-1.637224	.8054778

→ Model with two classes: $\widehat{WTP}_{sust}$ = -0.062 [=-(0.6722578/10.75694)] in the first and $\widehat{WTP}_{sust}$ = -0.524 [=-(0.8953473/1.708049)] in the second class

→ Model with three classes: $\widehat{WTP}_{sust}$ = -0.569 [=-(1.64287/2.888044)] in the first, $\widehat{WTP}_{sust}$ = -0.237 [=-(0.195132/0.8245511)] in the second, and $\widehat{WTP}_{sust}$ = -0.057 [=-(0.6403667/11.22759)] in the third class