A utility-based discrete choice model of satisficing behavior

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Motivation

- Stated preference methods are a leading tool for obtaining welfare measures for variety of environmental goods
- Discrete choice experiments are currently the most popular elicitation format
  - Allow for straightforward calculations of marginal WTP
  - Utilize a semi-panel structure to obtain more information from a single respondent

Discrete choice example

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Protection of ecologically valuable forests	**Status quo** Passive protection of **50%** of the most ecologically valuable forests (1.5% of all forests)	**Status quo** Passive protection of **50%** of the most ecologically valuable forests (1.5% of all forests)	**Status quo** Passive protection of **50%** of the most ecologically valuable forests (1.5% of all forests)	**Substantial improvement** Passive protection of 100% of the most ecologically valuable forests (3% of all forests, 100% increase)
Litter in forests	**Status quo** No change in the amount of litter in the forests	**Partial improvement** Decrease the amount of litter in the forests by half (50% reduction)	**Status quo** No change in the amount of litter in the forests	**Partial improvement** Decrease the amount of litter in the forests by half (50% reduction)
Infrastructure	**Status quo** No change in tourist infrastructure	**Status quo** No change in tourist infrastructure	**Partial improvement** Appropriate tourist infrastructure in an additional 50% of the forests (50% increase)	**Substantial improvement** Appropriate tourist infrastructure available in twice as many forests (100% increase)
Cost	0 PLN	10 PLN	25 PLN	100 PLN

Motivation

- Most models used to analyze data from DCE employ a random utility model (e.g. multinomial logit model)
  - Assume that individuals are rational, evaluate all alternatives and maximize their utility
    - Not very realistic in light of behavioral research
  - Allow for microeconomic inference
    - For example, welfare analysis using marginal rates of substitution, or willingness to pay
- Recently there is a growing interest in more behavioral models
  - Random regret minimization (Chorus et al., 2014)
  - Attribute-non-attendance (Scarpa et al., 2012)
  - Loss aversion (De Palma et al., 2008)
- Other heuristics are rarely investigated, as there is no modelling framework available

Satisficing

- Satisficing is a heuristics in which individual chooses alternative that is '*good enough*'
  - Individuals do not maximize utility
  - They make decision based on some aspiration level of the objective function
- Information about all alternatives is not readily available
  - Discovered sequentially through a search process
  - Search can be costly (e.g. time/cognitive cost)

Satisficing

- In discrete choice modelling literature there were three applications of this heuristic to date
  - Stüttgen, Boatwright and Monroe (2012)
  - Sandorf and Campbell (2018)
  - González-Valdés and de Dios Ortúzar (2018)
- Previous work employs attribute based inference, usually leading to a non-compensatory choice process
  - Individual choose first alternative for which all attributes levels meet given criteria
  - Or individuals may have criteria for only one attribute e.g. "*Choose first alternative that has cost lower than X PLN*"

Proposed model

- We propose a novel framework based on random utility model
- We assume that individual's utility from choosing given alternative is additive and includes stochastic component

$$U_{ij} = \mathbf{X}_{ij}\boldsymbol{\beta}_i + \varepsilon_{ij}$$

- We also assume that individuals have '*satisficing threshold*', ST_i , which describes their aspiration level for utility
  - In the sense, we built upon previous work on choice set formation

Proposed model

- Individual chooses first alternative for which utility exceeds satisficing threshold

	Alternative 1	Alternative 2	Alternative 3
Attribute 1	1	0	1
Attribute 2	2	3	1
Attribute 3	0	0	2

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Attribute 3	0	0	2

$$U_{i1} < ST_i$$

Proposed model

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Attribute 3	0	0	2

$U_{i1} < ST_i$ $U_{i2} > ST_i$

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- Individual chooses first alternative for which utility exceeds satisficing threshold

	Alternative 1	Alternative 2	Alternative 3
Attribute 1	1	0	1
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$U_{i1} < ST_i$ $\quad$ $U_{i2} > ST_i$ ← **Choice**

Proposed model

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Proposed model

- Individual chooses first alternative for which utility exceeds satisficing threshold

	Alternative 1	Alternative 2	Alternative 3
Attribute 1	1	0	1
Attribute 2	2	3	1
Attribute 3	0	0	2

$U_{i1} < ST_i$ $\quad U_{i2} < ST_i$ $\quad U_{i3} < ST_i$

Proposed model

- If none of the utilities exceed satisficing threshold, we assume that individual chooses the one with the highest utility

	Alternative 1	Alternative 2	Alternative 3
Attribute 1	1	0	1
Attribute 2	2	3	1
Attribute 3	0	0	2

Choice → $U_{i1} < ST_i$ $U_{i2} < ST_i$ $U_{i3} < ST_i$

If additionally: $U_{i1} > U_{i2} \wedge U_{i1} > U_{i3}$

Proposed model

- The conditional likelihood for the choice of alternative *j* becomes then

$$P\left(j \mid \boldsymbol{\beta}_i, ST_i\right) = \prod_{k=1}^{j-1} \exp\left(-\exp\left(\mathbf{X}_{ik}\boldsymbol{\beta}_i - ST_i\right)\right)\left(1 - \exp\left(-\exp\left(\mathbf{X}_{ij}\boldsymbol{\beta}_i - ST_i\right)\right)\right) +$$

$$+ \prod_{k=1}^{K}\left(\exp\left(-\exp\left(\mathbf{X}_{ik}\boldsymbol{\beta}_i - ST_i\right)\right)\right)\frac{\exp(\mathbf{X}_{ij}\boldsymbol{\beta}_i)}{\sum \exp(\mathbf{X}_{ik}\boldsymbol{\beta}_i)}$$

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Probability that previous alternatives do not exceed the threshold

Proposed model

- The conditional likelihood for the choice of alternative *j* becomes then

$$P\left(j \mid \boldsymbol{\beta}_i, ST_i\right)=\prod_{k=1}^{j-1} \exp\left(-\exp\left(\mathbf{X}_{ik}\boldsymbol{\beta}_i - ST_i\right)\right)\left(1-\exp\left(-\exp\left(\mathbf{X}_{ij}\boldsymbol{\beta}_i - ST_i\right)\right)\right)+$$

$$+\prod_{k=1}^{K}\left(\exp\left(-\exp\left(\mathbf{X}_{ik}\boldsymbol{\beta}_i - ST_i\right)\right)\right)\frac{\exp(\mathbf{X}_{ij}\boldsymbol{\beta}_i)}{\sum \exp(\mathbf{X}_{ik}\boldsymbol{\beta}_i)}$$

Probability that alternative *j* does exceed the threshold

Proposed model

- The conditional likelihood for the choice of alternative *j* becomes then

$$P\left(j \mid \boldsymbol{\beta}_i, ST_i\right) = \prod_{k=1}^{j-1} \exp\left(-\exp\left(\mathbf{X}_{ik}\boldsymbol{\beta}_i - ST_i\right)\right)\left(1 - \exp\left(-\exp\left(\mathbf{X}_{ij}\boldsymbol{\beta}_i - ST_i\right)\right)\right) +$$

$$+ \prod_{k=1}^{K}\left(\exp\left(-\exp\left(\mathbf{X}_{ik}\boldsymbol{\beta}_i - ST_i\right)\right)\right) \frac{\exp(\mathbf{X}_{ij}\boldsymbol{\beta}_i)}{\sum \exp(\mathbf{X}_{ik}\boldsymbol{\beta}_i)}$$

Probability that none of the alternatives exceed the threshold

Proposed model

- The conditional likelihood for the choice of alternative *j* becomes then

$$P\left(j \mid \boldsymbol{\beta}_i, ST_i \right) = \prod_{k=1}^{j-1} \exp\left(-\exp\left(\mathbf{X}_{ik}\boldsymbol{\beta}_i - ST_i\right)\right)\left(1-\exp\left(-\exp\left(\mathbf{X}_{ij}\boldsymbol{\beta}_i - ST_i\right)\right)\right) +$$

$$+\prod_{k=1}^{K}\left(\exp\left(-\exp\left(\mathbf{X}_{ik}\boldsymbol{\beta}_i - ST_i\right)\right)\right)\frac{\exp(\mathbf{X}_{ij}\boldsymbol{\beta}_i)}{\sum \exp(\mathbf{X}_{ik}\boldsymbol{\beta}_i)}$$

Probability that alternative *j* maximizes utility

Proposed model

- Preference heterogeneity can be easily incorporated
  - Similarly as in mixed logit
    - In current application we assume that all parameters are random and correlated (normally or log-normally distributed)
    - Satisficing threshold is also random and follows normal distribution
- Model is extended to incorporate stochastic satisficing
- If satisficing threshold is very large then model becomes a regular random utility model
  - Straightforward to test for satisficing behavior even in the field
- Marginal rates of substitution can be easily calculated as ratio of parameters

Data

- Discrete Choice Experiment conducted on representative sample of 1001 Poles
- Objective of the study was to analyze preferences towards different programs of forest management in Poland
- 4 attributes
  - Passive protection of most ecologically valuable forests (Levels: 50% (SQ), 75%, 100%)
  - Amount of litter (Levels: No change, 50% reduction, 90% reduction)
  - Infrastructure for tourists (Levels: No change, Infrastructure in 50% additional forests, Infrastructure in 100% additional forests)
  - Cost (Levels: 0, 10, 25, 50, 100 PLN annually)
- 4 alternatives (including *status quo*), 26 choice tasks

Choice task example

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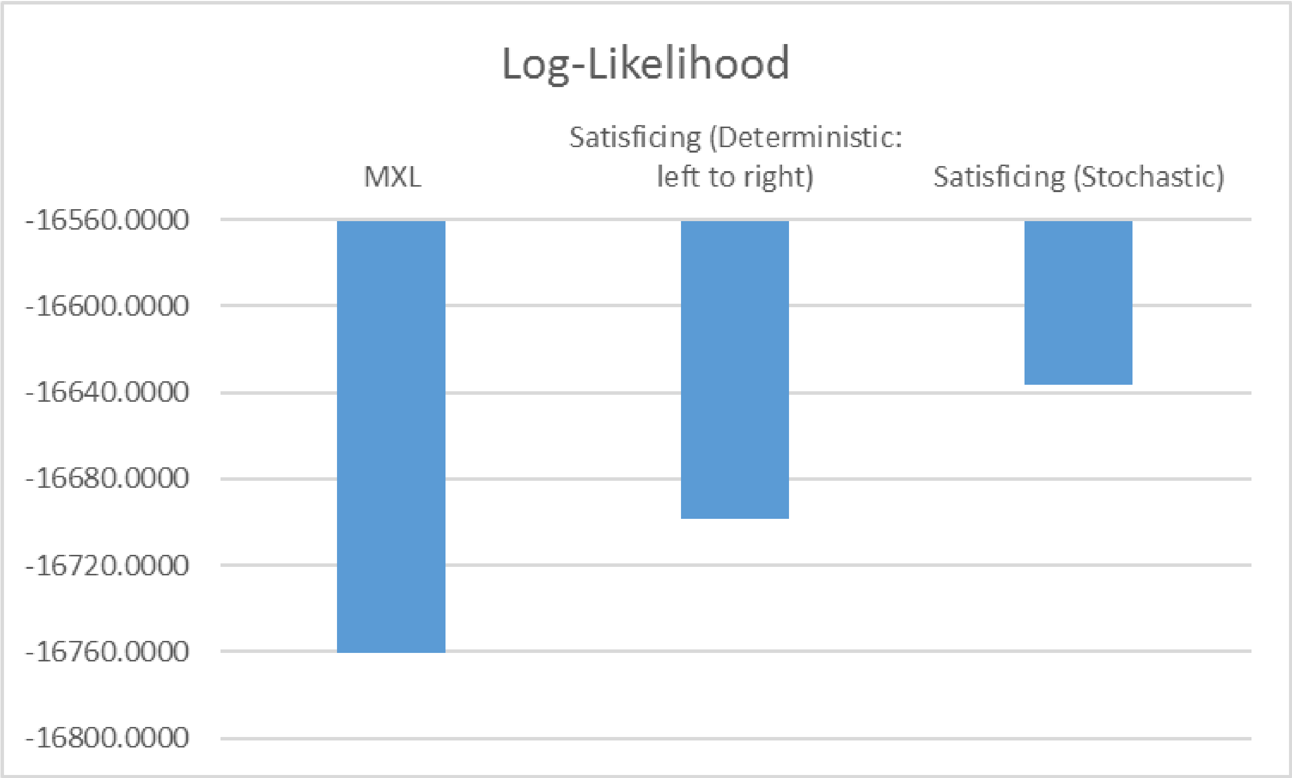
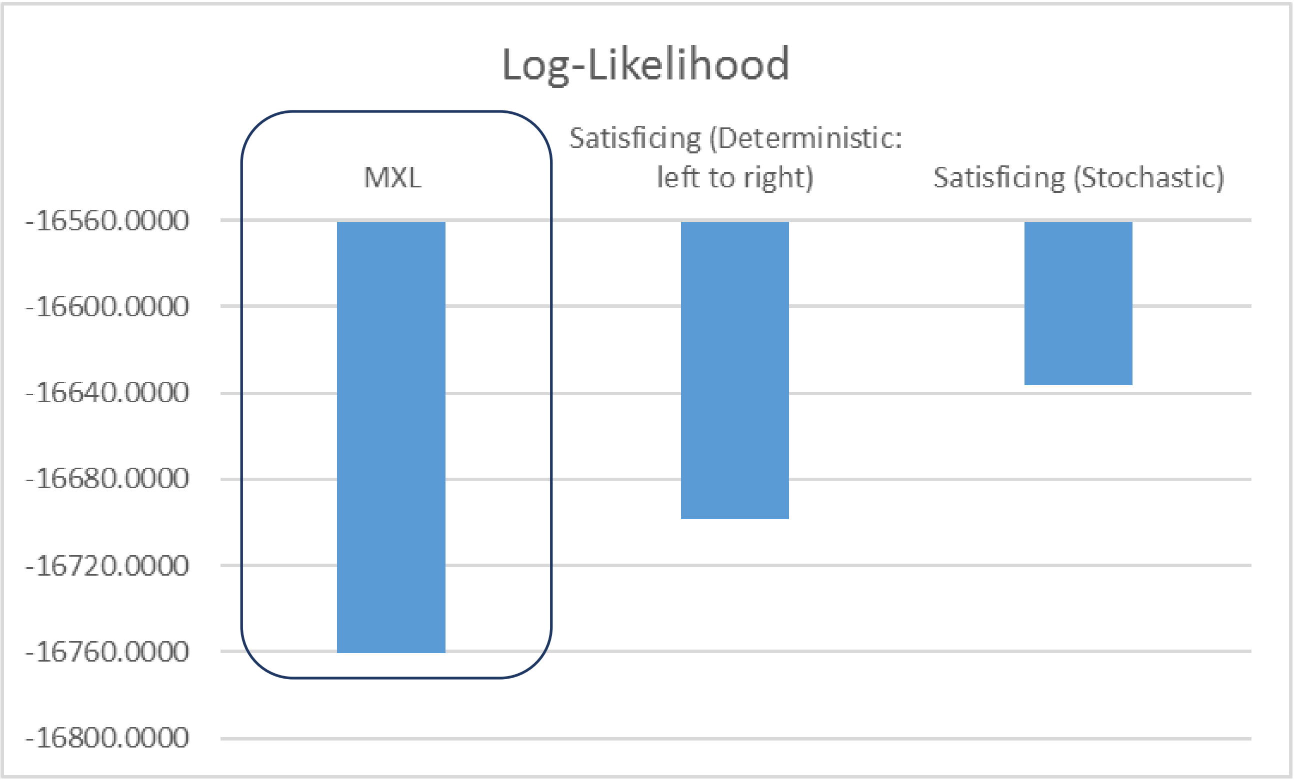
Results



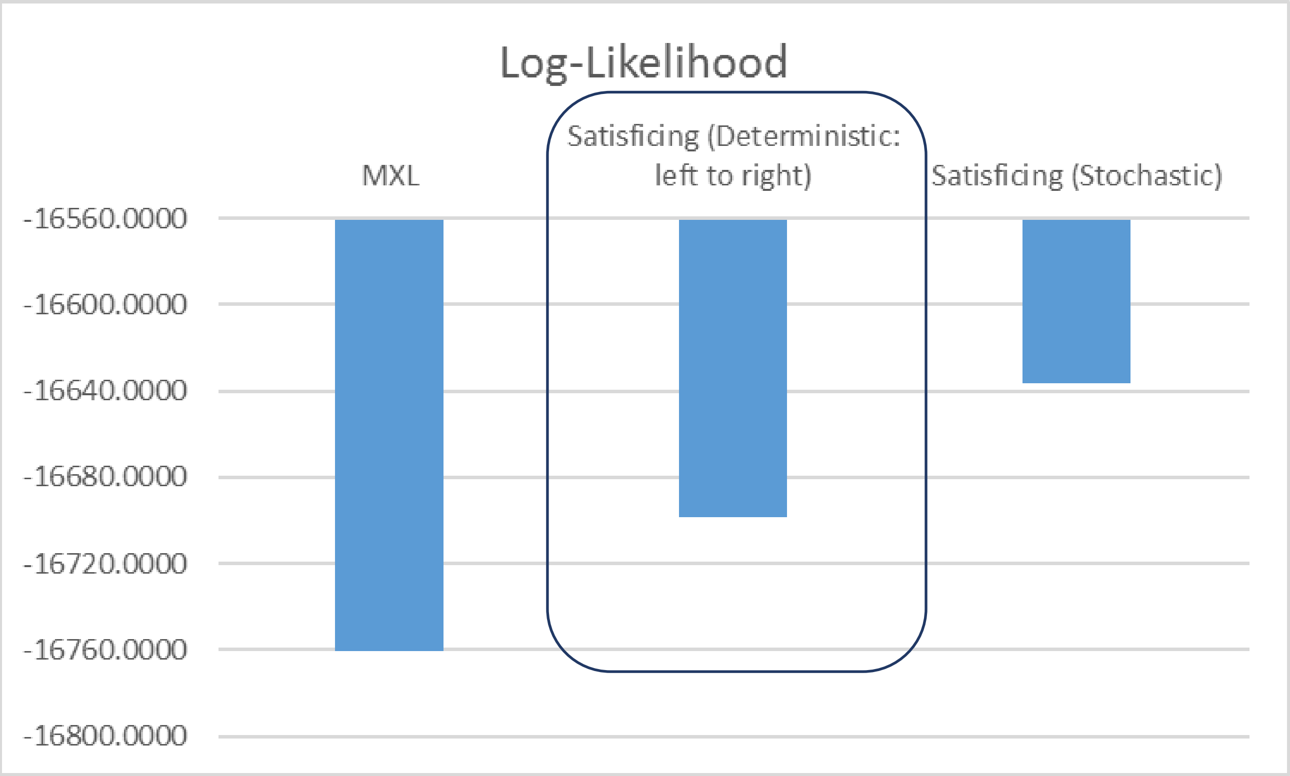
- We compare 3 models:

Results



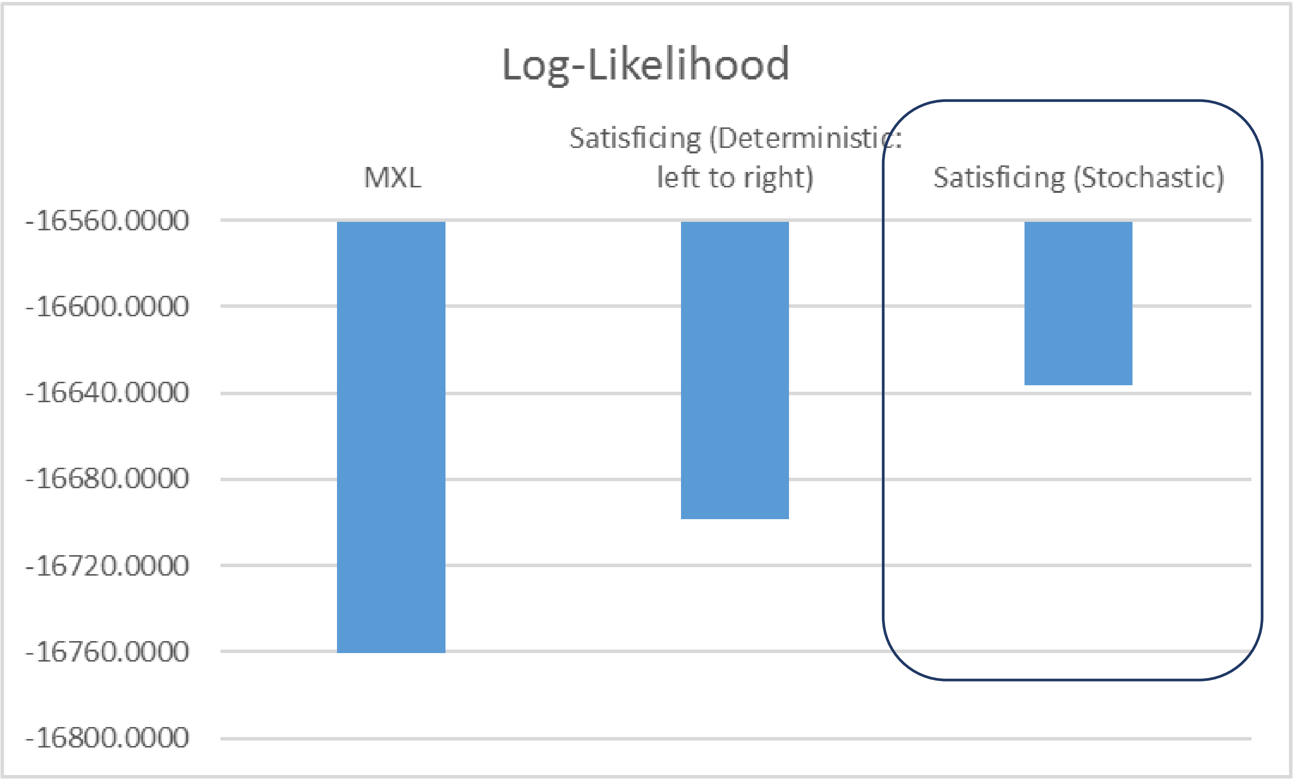
- We compare 3 models:
  - Basic mixed logit (MXL)
    - Random utility
    - No satisficing

Results



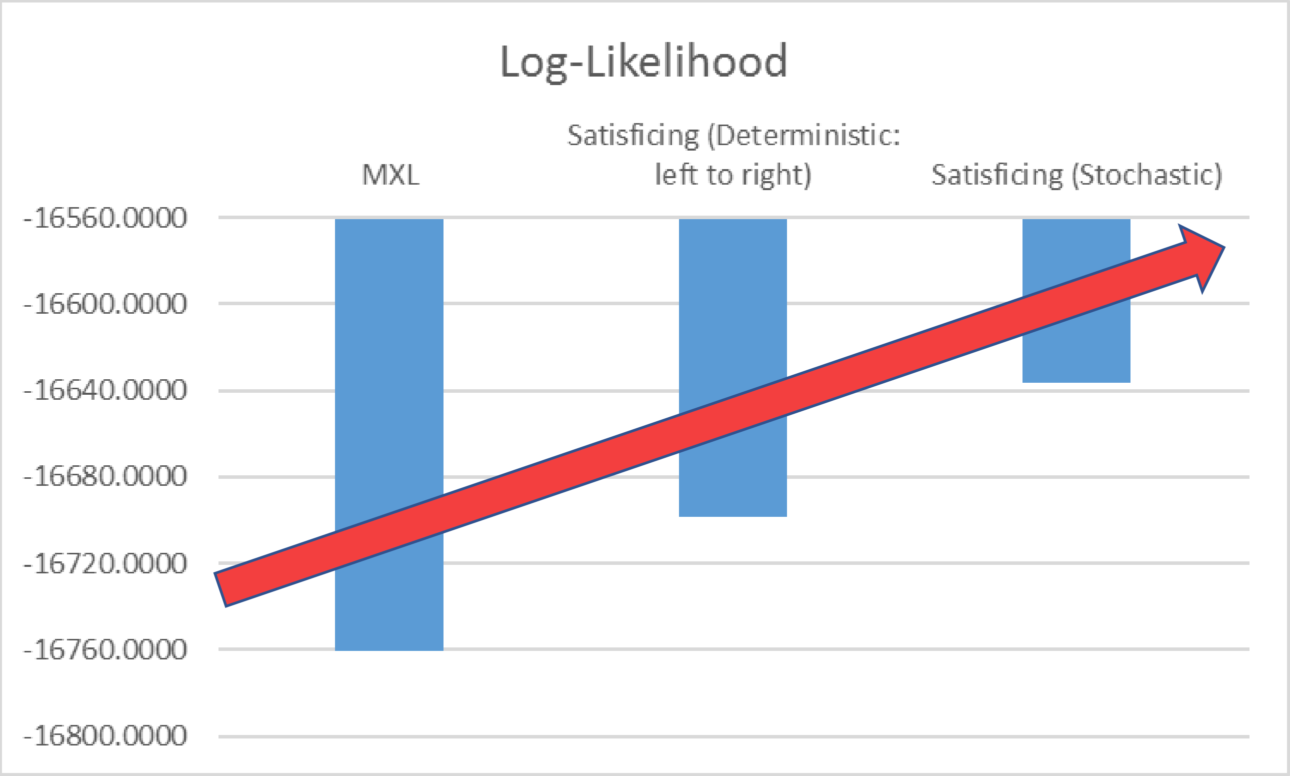
- We compare 3 models:
  - Satisficing Mixed Logit
    - Order in which individuals evaluate alternative is fixed
    - It is assumed that individuals go from left to right

Results



- We compare 3 models:
  - Stochastic Satisficing Mixed Logit
    - Order in which individuals evaluate alternative is random
      - From the researcher perspective
    - Different orders can have different probabilities

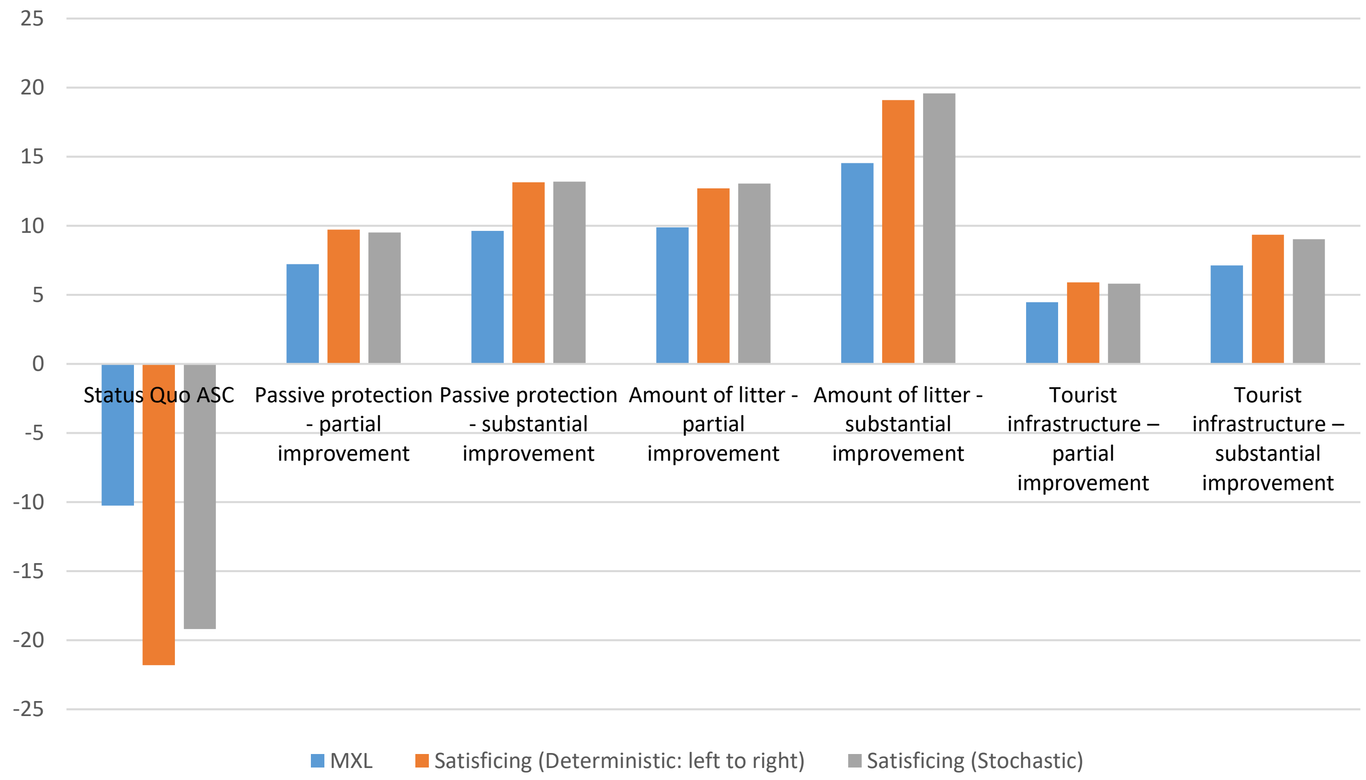
Results



- We compare 3 models:
  - Log-likelihood is increasing significantly
  - 3rd model provides the best fit to data
  - The same conclusion when using AIC or BIC

Results

- There are significant differences in median WTP estimates when using satisficing model
  - Higher WTP for most attributes
  - Lower for Status Quo



Results

- Probability of being ‘*satisfied*’ with a given alternative is rather low
  - Dual role of satisficing threshold

	Substantial improvement in all attributes, cost is 10 PLN	**Partial improvement in all attributes, cost is 10 PLN**	**Substantial improvement in amount of litter, partial improvement in the rest of attributes, cost is 25 PLN**	**Status Quo**
Satisficing (Deterministic: left to right)	20.27%	13.94%	15.41%	1.25%
Satisficing (Stochastic)	19.59%	13.87%	15.10%	1.67%

Results

- There is a significant decision process heterogeneity with Stochastic Satisficing
  - Different orders evaluated with different probabilities

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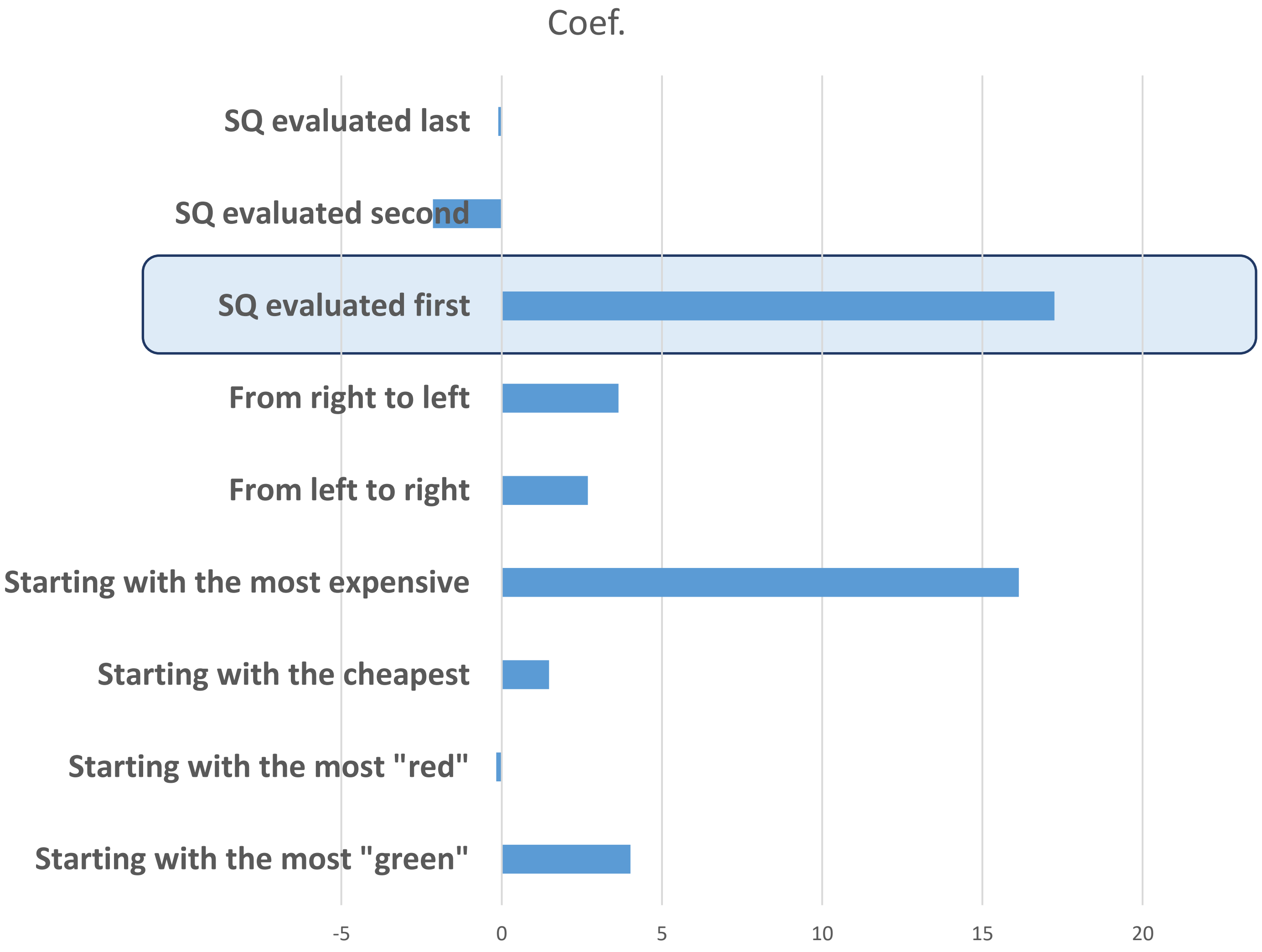
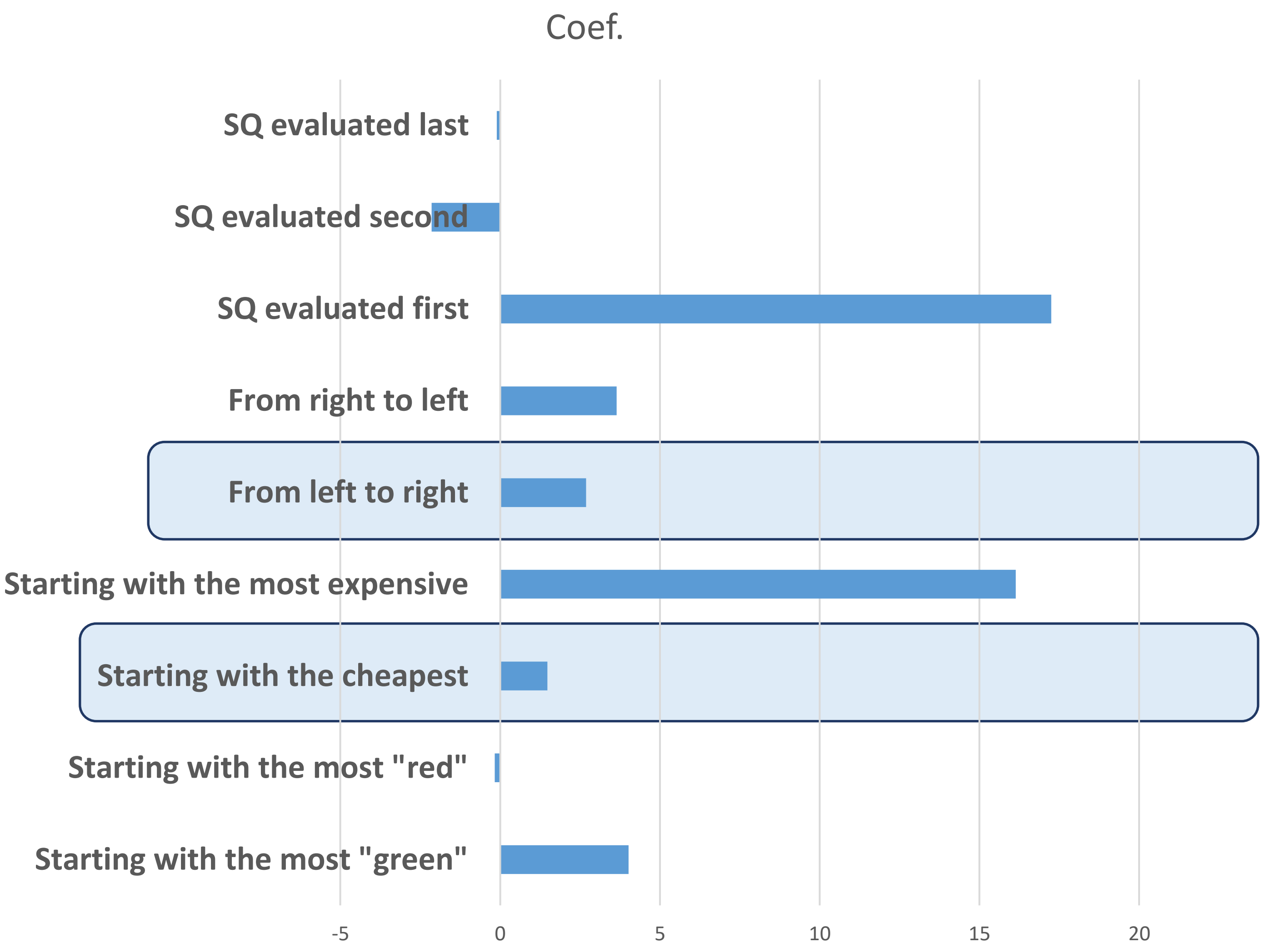
  - Different orders evaluated with different probabilities
  - High probability of starting with a SQ alternative



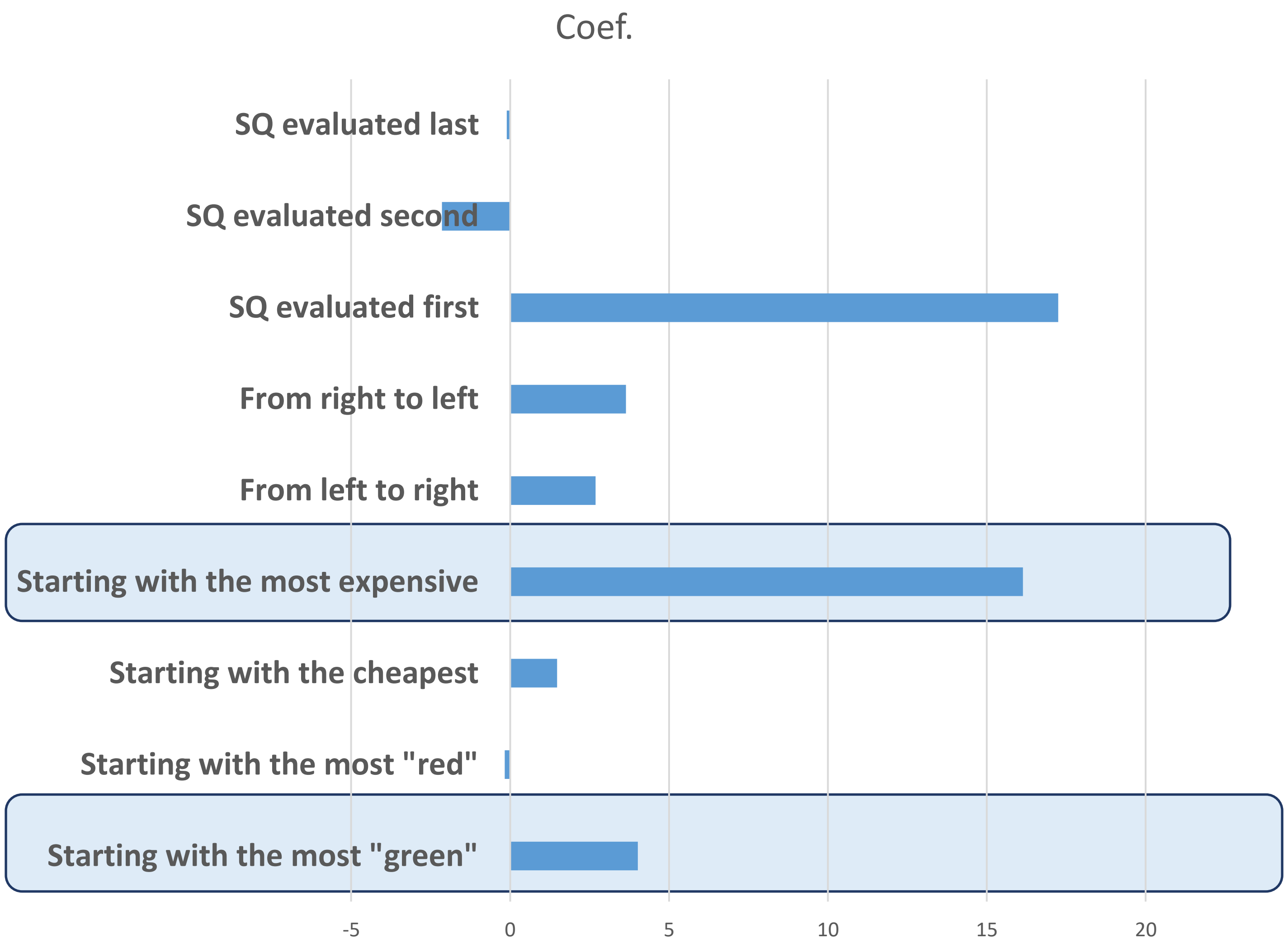
Results

- There is a significant decision process heterogeneity with Stochastic Satisficing
    - Different orders evaluated with different probabilities
    - High probability of starting with a SQ alternative
        - But not only ‘*left to right*’ order is significant



Results

- There is a significant decision process heterogeneity with Stochastic Satisficing
  - Different orders evaluated with different probabilities
  - High probability of starting with a SQ alternative
    - But not only '*left to right*' order is significant
  - Some orders which do not start with SQ are also possible



Conclusions

- The proposed model leads to a significant improvement in fit to data
  - Satisficing behavior affects WTP estimates
  - Satisficing threshold is not straightforward to interpret
    - It seems that large portion of the sample would still employ RUM (not satisfied with any alternative)
- Future work
  - Analyzing more datasets
  - Compare model performance with satisficing models previously proposed in the literature
  - Using eye-tracking data?

References

- Chorus, C., van Cranenburgh, S., & Dekker, T. (2014). Random regret minimization for consumer choice modeling: Assessment of empirical evidence. *Journal of Business Research*, *67*(11), 2428-2436.
- De Palma, A., Ben-Akiva, M., Brownstone, D., Holt, C., Magnac, T., McFadden, D., ... & Walker, J. (2008). Risk, uncertainty and discrete choice models. *Marketing Letters*, *19*(3-4), 269-285.
- González-Valdés, F., & de Dios Ortúzar, J. (2018). The Stochastic Satisficing model: A bounded rationality discrete choice model. *Journal of choice modelling*, *27*, 74-87.
- Sandorf, E. D., & Campbell, D. (2018). Accommodating satisficing behaviour in stated choice experiments. *European Review of Agricultural Economics*, *46*(1), 133-162.
- Scarpa, R., Zanoli, R., Bruschi, V., & Naspetti, S. (2012). Inferred and stated attribute non-attendance in food choice experiments. *American Journal of Agricultural Economics*, *95*(1), 165-180.
- Stüttgen, P., Boatwright, P., & Monroe, R. T. (2012). A satisficing choice model. *Marketing Science*, *31*(6), 878-899.