Institute for Transport Studies
FACULTY OF ENVIRONMENT

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Conflicting interpretations of respondent heterogeneity

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Outline

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- Introduction
- Outlying sensitivities
- Heterogeneity in information processing strategies
- Heterogeneity in decision rules

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Introduction I

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- Applications using discrete choice models increasingly incorporate a random treatment of unexplained respondent heteogeneity
- Mainly in the form of Mixed Multinomial Logit models, along with a handful of applications using more general GEV mixture approaches
- For application, no longer just interested in mean measures of sensitivity/WTP, but also variation in population
- Reducing amount of effort going into explaining taste heterogeneity in a deterministic manner, which would arguably be preferable for interpretation and model application (e.g. forecasting)

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Introduction II

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- When incorporating a random treatment of heterogeneity, analyst should aim to minimise the impact of model specification on findings
  - ⋆ Significant body of research looking at implications of distributional assumptions in these models
- Should also aim to reduce the part of heterogeneity that is picked up by random component
  - ⋆ link some heterogeneity to socio-demographic characteristics

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Introduction III

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- Can our findings in terms of heterogeneity be unduly influenced by specific behavioural processes?
  - ⋆ Pinjari & Bhat (2006): unexplained non-linearities in response can manifest themselves as random taste heterogeneity
  - ⋆ de Borger & Fosgerau (2008): unexplained reference dependence can lead to biased heterogeneity findings
- This presentation:
  - ⋆ what do our findings in terms of heterogeneity actually tell us?
  - ⋆ can the behaviour of a few respondents have a large influence on our overall findings?
    - ∗ in terms of mean valuations as well as heterogeneity

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Outlying sensitivities I

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- Work by Campbell, Hess, Rose & Scarpa (2009) on simulated data and Campbell & Hess (2009) on SP data
- Presence of a few respondents with extreme sensitivities can have a very significant influence on findings in terms of heterogeneity when making use of *standard* distributions
  - ⋆ impact also on mean valuations, which are crucial for application, policy work, etc
- Use of non-parameteric distributions or mixtures of distributions appealing in this context
  - ⋆ e.g. mixture of three continuous distributions, with a small lower and upper outlier group, along with a large central group

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Outlying sensitivities II

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- Findings show that such an approach can significantly reduce the extent of random heterogeneity in the remainder of the data
  - ⋆ Very difficult to use in practice, especially with large datasets and choice sets
- No attempt to explain *extreme* sensitivities
- Two possible interpretations offered in this presentation

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Heterogeneous IPS I

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- Growing recognition that different respondents process information presented in SP surveys in different ways
- Examples:
  - ⋆ respondents may ignore one or more of the attributes
  - ⋆ respondents may process several of the attributes jointly
- Direct questions about information processing strategies (IPS) seem to confirm this
- Lack of treatment of IPS heterogeneity is likely to affect findings in terms of overall respondent heterogeneity, as well as mean findings

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Heterogeneous IPS II

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- Hess & Hensher (2010)
- Data from an Australian toll road study
- Five attributes: free flow travel time, slowed down travel time, travel time variability, running costs, toll
- High rates of stated attribute ignoring
- Previous work had relied on setting attributes to zero for specific respondents
- Two problems:
  - ⋆ Endogeneity
  - ⋆ Can we really believe what respondents are telling us?

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Heterogeneous IPS III

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- Rather than using *stated* IPS, attempt to infer strategies from the data
- Estimate MMNL model on full data, and produce conditional distributions for each attribute for each respondent
- Assign respondents to ignoring/non-ignoring classes on the basis of probability that sensitivity for a given attribute is zero
  - ⋆ some very visible differences in group allocation
  - ⋆ also, rates much lower (e.g. 2% for tolls instead of 9%)
- Unlike with stated information approach, models show that sensitivities in the inferred ignoring group are indeed equal to zero

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Heterogeneous IPS IV

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- Impact on heterogeneity findings
- Use coefficient of variation as an indication

	Base model	Inferred IPS		
adj. ρ^2	0.4492	0.4696		
			Reductions	
	c.v.	c.v.	het	resp
β_{FFT}	0.98	0.75	-23.65%	-15.61%
β_{SDT}	0.72	0.68	-5.47%	-2.44%
β_{RC}	0.78	0.63	-19.39%	-5.37%
β_{TOLL}	0.57	0.57	-0.01%	-1.95%
β_{VAR}	3.97	2.76	-30.49%	-29.27%

- For three attributes, *ignoring* respondents accounted for disproportionally large share of heterogeneity

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Heterogeneous decision rules I

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- Various pieces of work looking at subsets of respondents behaving in a different manner
- But models tend to still assume that the actual decision rule (i.e. compensatory behaviour) still applies across respondents
- There is however also ample evidence to suggest that some respondents employ other decision rules
- One example is lexicographic behaviour
  - ⋆ choose alternative that dominates on most important attribute
  - ⋆ in case of ties, concerned alternatives are retained, and we move to the second most important attribute
  - ⋆ ordering of attributes varies across respondents

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Heterogeneous decision rules II

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- Lexicographic behaviour especially easy to spot in the case of surveys with only two attributes
- In surveys with more attributes, many different rules are possible (involving different orderings as well as numbers of levels)
- Presence of lexicographic respondents can not only change retrieved mean sensitivities (and WTP measures) but also inflate the retrieved degree of heterogeneity
  - ⋆ models will attempt to explain non-trading behaviour through extreme sensitivities

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Heterogeneous decision rules III

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- Past work:
  - ⋆ ignore presence of lexicographic behaviour
    - ∗ likely to impact on estimates
  - ⋆ remove lexicographic respondents
    - ∗ this in effect assumes that these respondents were definitely not behaving in a compensatory manner
    - ∗ but: incentives may simply not have been large enough
  - ⋆ attempt to accommodate lexicographic respondents
    - ∗ work by Rigby et *al*. uses a latent class structure where in the lexicographic class, only a single coefficient is used
      - · assumes that respondents ignored all other attributes
      - · would still give a non-zero probability to the dominated alternative
      - · remaining coefficient could become very large

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Heterogeneous decision rules IV

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- Proposed modelling framework: combine compensatory model with dominance based models
- Let $P_n(R_1)$ be the probability for the sequence of choices observed for respondent n, under the assumption that decision rule R_1 was used
- In a standard MNL model, we would thus have

$$P_n(R_1) = \prod_{t=1}^{T} \frac{e^{V_{j_{nt}}}}{\sum_{j=1}^{J} e^{V_j}}$$

where $V_{j_{nt}}$ is the modelled utility of the alternative chosen by respondent n in choice situation t

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Heterogeneous decision rules V

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- Probability for sequence of choices observed for respondent n:

$$P_n = \sum_{r=1}^{R} \pi_{n,r} P_n(R_r) \quad \text{where} \quad \sum_{r=1}^{R} \pi_{n,r} = 1 \quad \text{and} \; 0 \leq \pi_r \leq 1 \; \forall r$$

- Let us further assume that R_1 corresponds to the compensatory model, where we make use of a Mixed Logit model, such that:

$$P_n(R_1) = \int_{\beta} \prod_{t=1}^{T} \frac{e^{V_{j_{nt}}}}{\sum_{j=1}^{J} e^{V_j}} f(\beta \mid \Omega) \, \mathrm{d}\beta$$

- Remaining rules are dominance based rules

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Heterogeneous decision rules VI

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- Example: two attributes, time and money, where rule 2 is lexicography on time (tt), and rule 3 is lexicography on cost (tc)

$$P_n(R_2) = \prod_{t=1}^{T} \delta_{TT_{jnt}}$$

where $\delta_{TT_{jnt}}$ is equal to 1 if the travel time for the alternative chosen by respondent n in choice set t is less than that of any of the other available alternatives

$$P_n(R_3) = \prod_{t=1}^{T} \delta_{TC_{jnt}}$$

where $\delta_{TC_{jnt}}$ is defined analogously to equal to $\delta_{TT_{jnt}}$

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Heterogeneous decision rules VII

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- The probability under a given lexicographic rule will be equal to 1 only if every single choice for that respondent can be explained by that rule
- This will only apply for some respondents
- In models with more than two attributes, multiple rules may be able to explain the same sequence of choices (depending on the design) and some normalisation may be required
- Need to estimate parameters of choice model in class 1 as well as the probabilities for all classes
  - ⋆ could also link class allocation to socio-demographic characteristics

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Heterogeneous decision rules VIII

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- Application I: Danish Valuation of Travel Time Savings (VTTS) data
- Binary design, with two alternatives (time and money)
- $1,676$ respondents, each with 8 choices
- 13.66% of respondents always choose cheapest, with 5.97% of respondents always choosing fastest
- Removing these respondents has the obvious impacts on results, but is also very arbitrary
- But their simple inclusion in the models, without treatment, arguably biases the findings in terms of heterogeneity

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Heterogeneous decision rules VIII

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- Four different models estimated
  - ⋆ MNL model
    - ∗ no treatment of lexicography, or random heterogeneity
  - ⋆ LC model
    - ∗ lexicography accommodated solely through special classes, with no attempts to explain through taste heterogeneity
  - ⋆ MMNL model
    - ∗ no special treatment of lexicography; explained solely through taste heterogeneity
  - ⋆ LC-MMNL model
    - ∗ special classes for lexicography that *cannot* be explained through heterogeneity, but with attempts to accommodate some through heterogeneity

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Heterogeneous decision rules IX

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- Along with time and cost sensitivity, estimate a constant for first alternative
- Random heterogeneity accommodated through multivariate Lognormal distribution

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Heterogeneous decision rules X

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	MNL	LC	MMNL	LC-MMNL
LL	-8,925.89	-8,030.10	-7,360.77	-7,350.33
par.	3	5	5	7
adj. ρ^2	0.0393	0.1354	0.2074	0.2084
Trading	100%	81%	100%	90%
Lex-cost	0%	13%	0%	7%
Lex-time	0%	6%	0%	3%

- LC model retrieves existing size of lexicographic classes, while LC-MMNL model attempts to explain some of the behaviour through heterogeneity, without however going as far as MMNL model

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Heterogeneous decision rules XI

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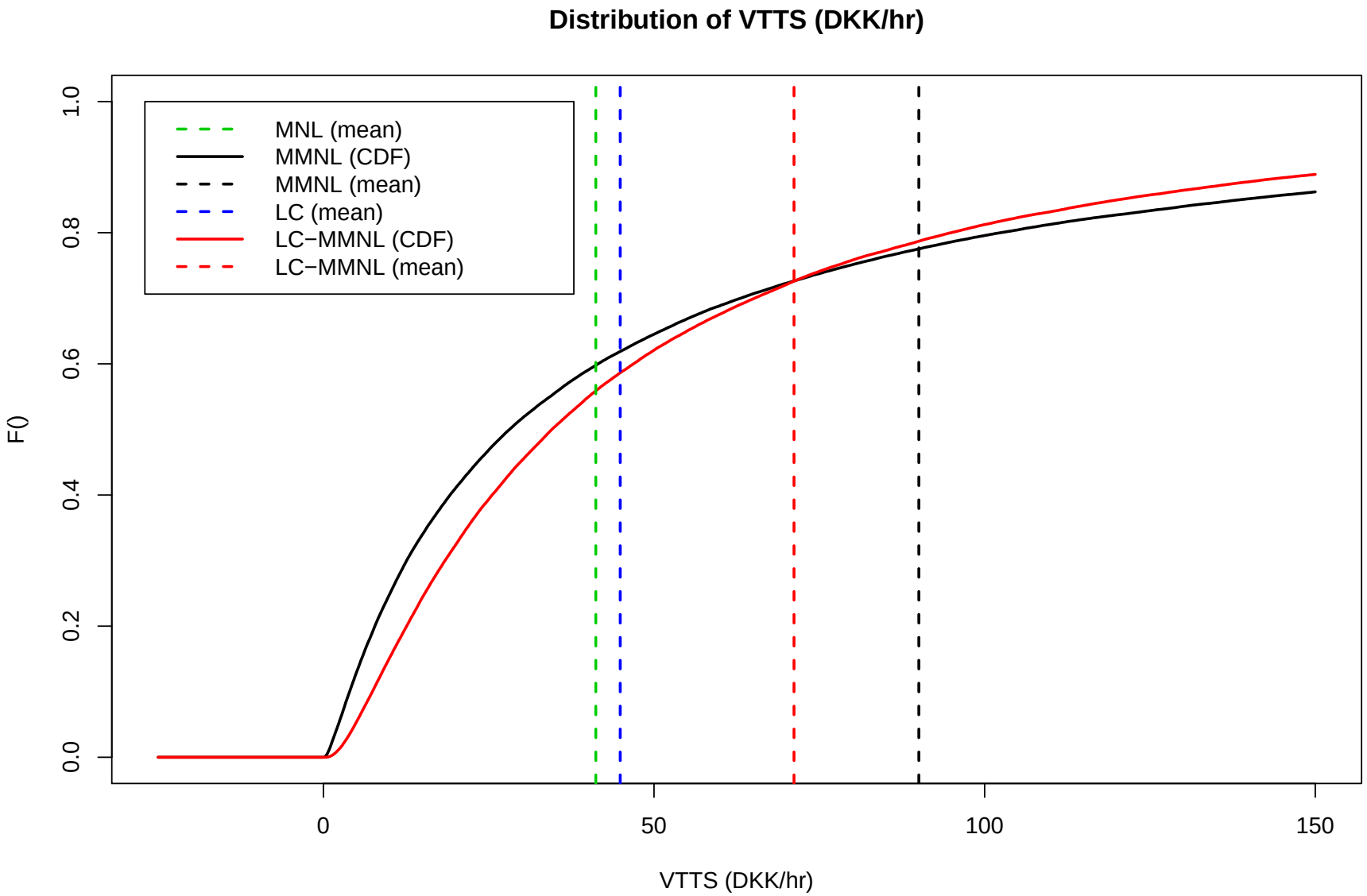

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Heterogeneous decision rules XII

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- Evidence of reduced heterogeneity
- Degree of reduction very substantial compared to retrieved rates of lexicography

	VTTS					
	mean	median	st.dev.	c.v.	c.v. (β_{TT})	c.v. (β_{TC})
MNL	41.19		-	0	0	0
LC	44.89		-	0	0	0
MMNL	90.66	28.21	261.94	2.89	5.45	17.80
LC-MMNL	70.61	34.60	123.07	1.74	3.47	7.98

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Heterogeneous decision rules XIII

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- Application II: Survey for rail and bus commuters
- Three alternatives (first is status quo)
- Five attributes (travel time, fare, crowding, expected delay, provision of delay information system)
- Make use of constant for first two alternatives, four marginal utility coefficients, two coefficients for non-zero levels for information attribute
- Use Lognormals for four first coefficients, and Normals for final two, with full correlation structure

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Heterogeneous decision rules XIV

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- 5 single attribute rules (never applicable), 20 two attribute rules, 60 three attribute rules, 120 four attribute rules, and 120 five attribute rules (never applicable)

- Narrowed this down to 6 decision rules (along with compensatory)

1. fare - time - crowding
2. fare - info - reliability
3. crowding - fare - time
4. fare - crowding - info - reliability
5. crowding - reliability - fare - time
6. reliability - crowding - time - fare

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Heterogeneous decision rules XV

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	MNL	LC	MMNL	LC-MMNL
LL	-3,392.35	-3,245.62	-2,967.51	-2,945.76
par	8	14	29	35
adj. ρ^2	0.1589	0.1937	0.2588	0.2627
trading	100%	90.11%	100%	96.51%
fare-time-crowding		3.08%		0.00%
fare-info-reliability		0.82%		0.32%
crowding-fare-time		0.95%		0.55%
fare-crowding-info-reliability		3.04%		0.98%
crowding-reliability-fare-time		0.50%		0.44%
reliability-crowding-time-fare		1.49%		1.22%

- Much smaller rates than in Danish data
  - ⋆ was to be expected
    - ∗ survey actively encouraged trading and avoided dominance

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Heterogeneous decision rules XV

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- Overall: evidence of reduced heterogeneity in WTP measures
- Exception: travel time, which was not well represented in decision rules

			MMNL			LC-MMNL		
WTP	MNL	LC	mean	median	c.v.	mean	median	c.v.
travel time (£/hr)	1.23	1.43	2.51	1.79	0.97	2.61	1.26	1.76
crowding	0.98	1.06	2.90	0.72	3.68	2.19	0.63	3.21
expected delay	0.47	0.52	2.20	0.56	3.33	1.73	0.59	2.60
info service (charged)	-0.04	-0.03	-0.09	-0.06	22.62	-0.13	-0.05	11.40
info service (free)	0.15	0.19	0.59	0.10	4.11	0.56	0.12	3.48

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Heterogeneous decision rules XVI

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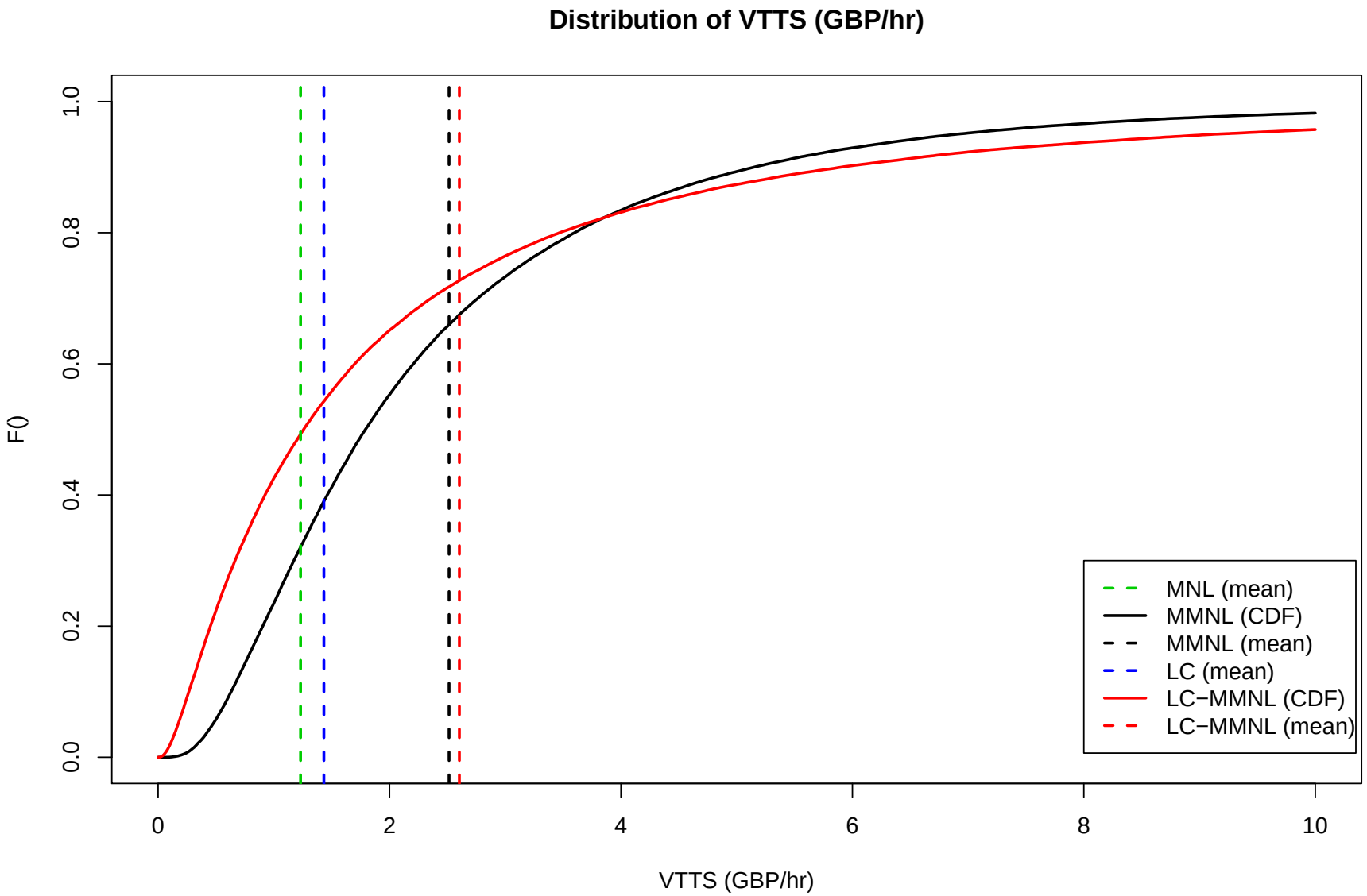

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Heterogeneous decision rules XVII

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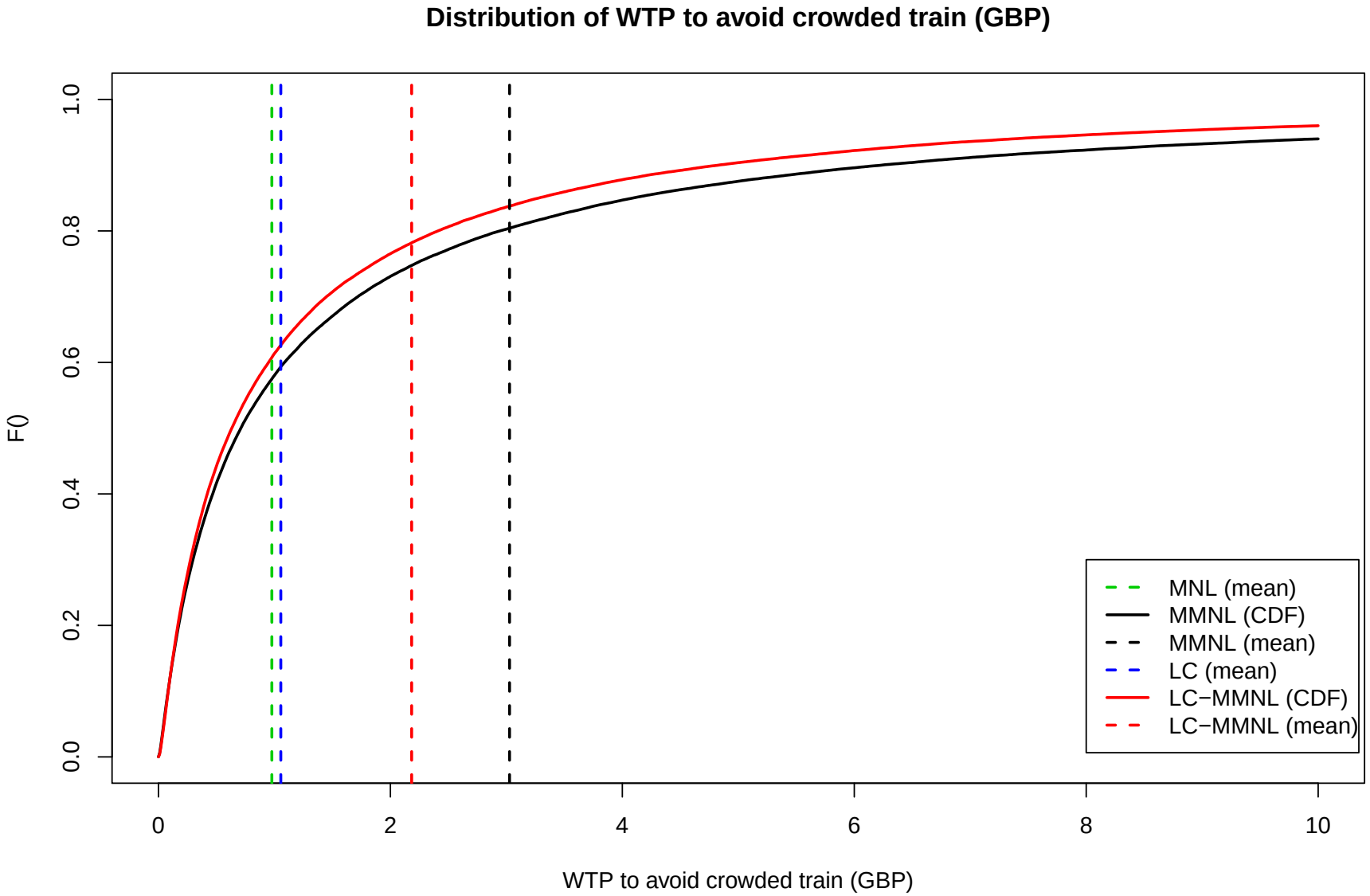

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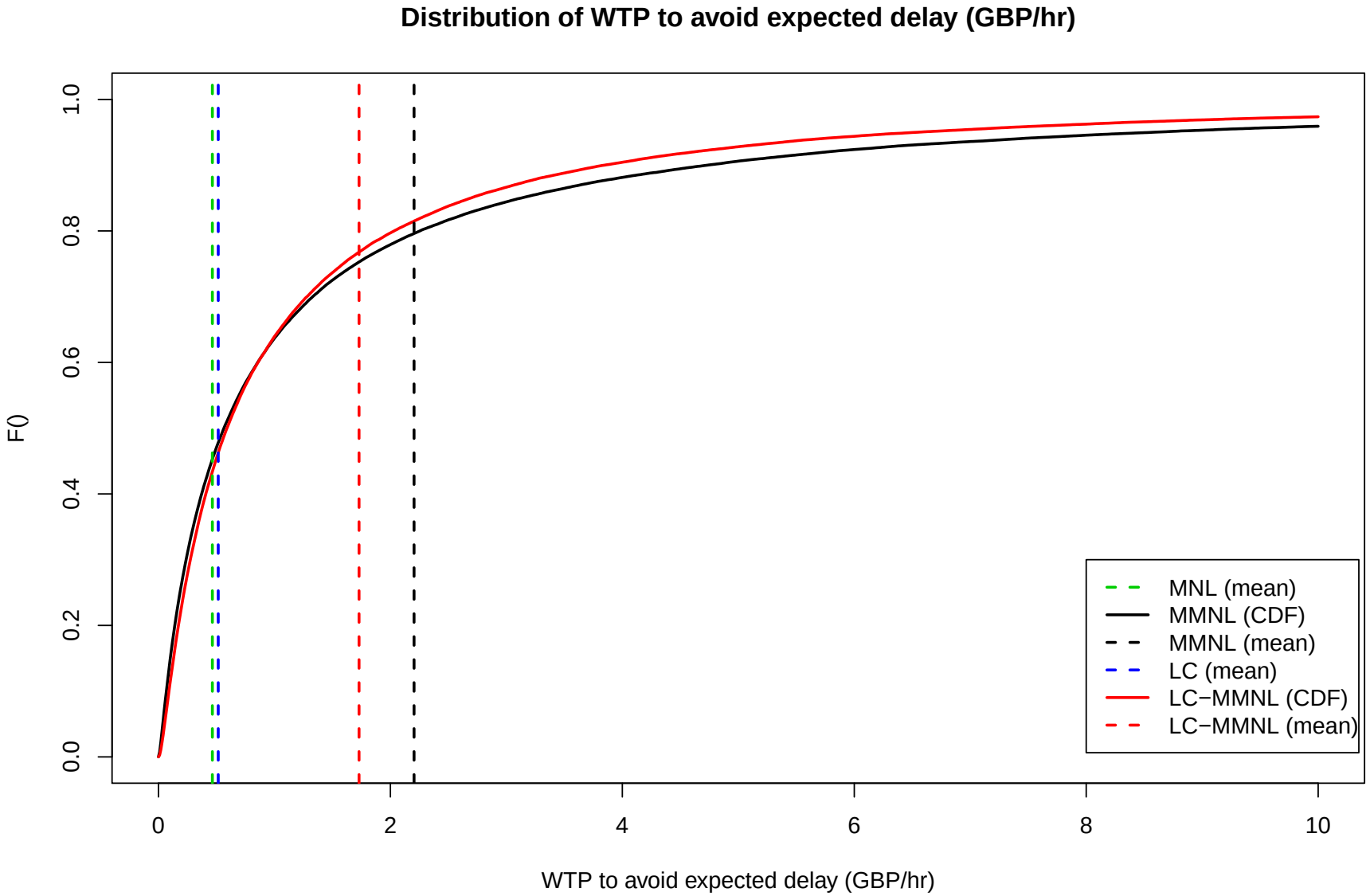

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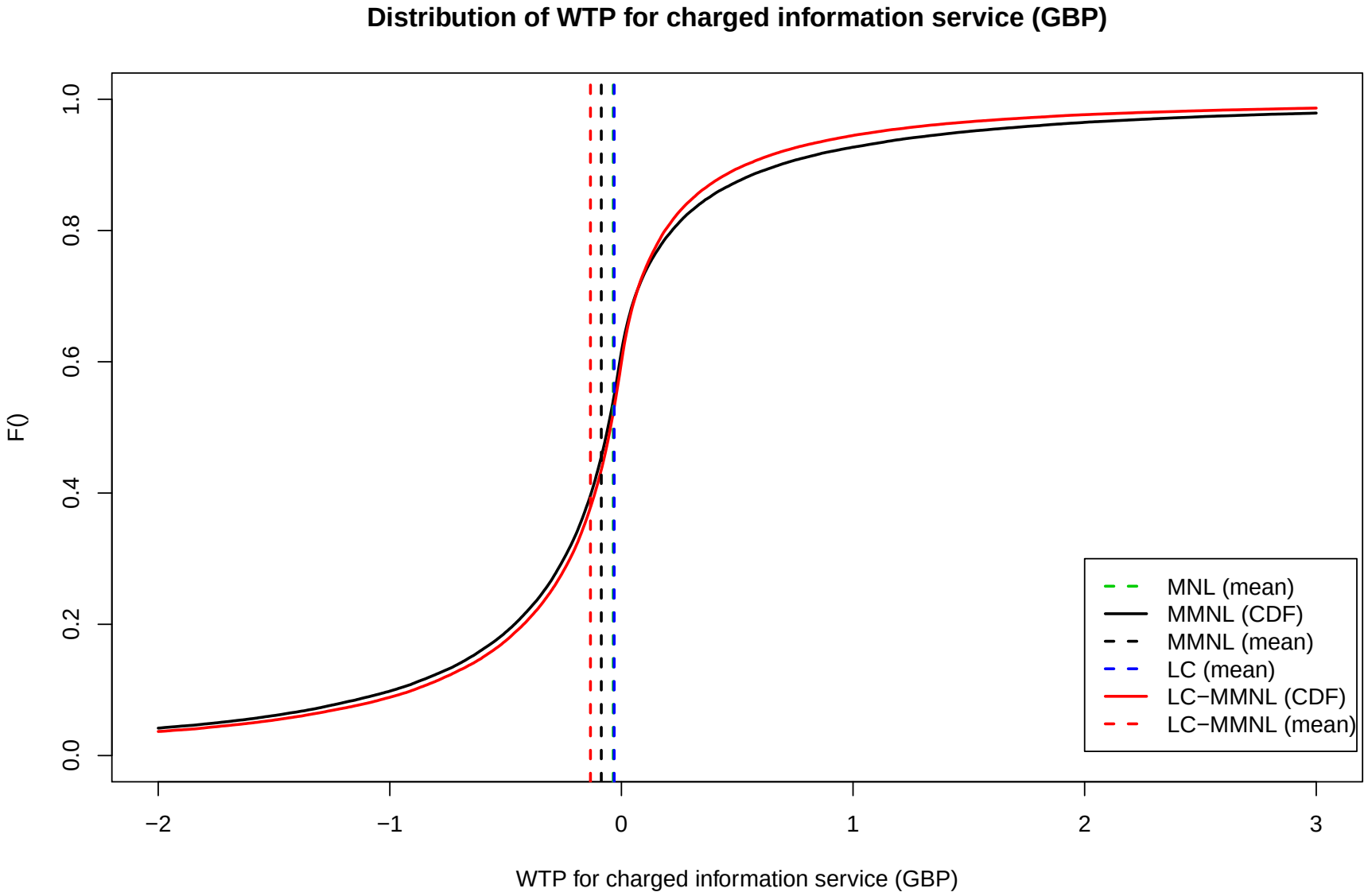

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Heterogeneous decision rules XX

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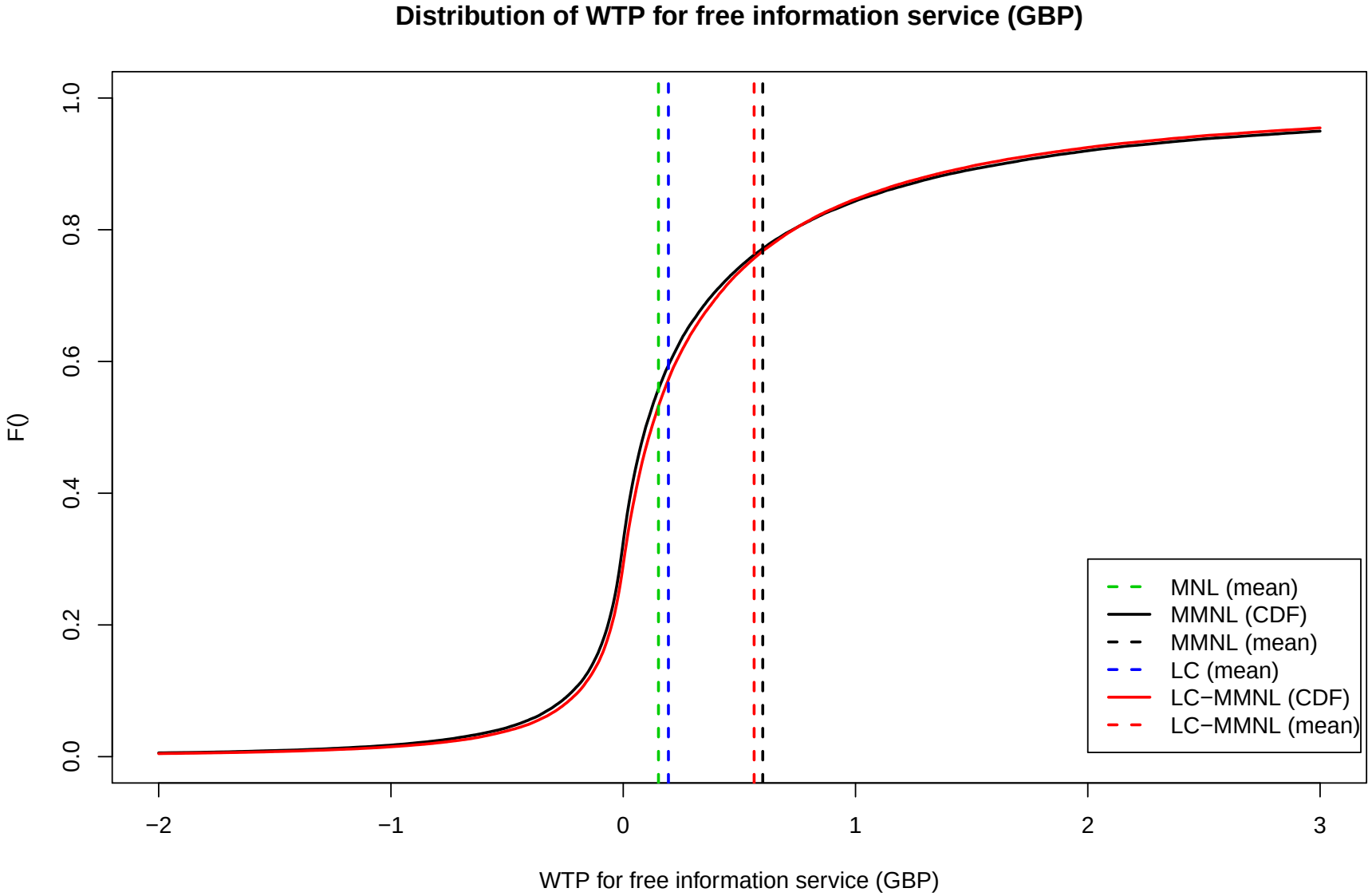

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Heterogeneous decision rules XXI

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- Evidence from two datasets
- Different scope for and rates of lexicographic behaviour
- In both datasets, mixed compensatory and dominance based model obtains significant improvements in model fit
- Evidence that small number of respondents account for large share of retrieved heterogeneity in base models
- But simply removing respondents is not advisable as their behaviour may be a reflection of sensitivities that are outside the incentives presented
- Additionally, in more complex surveys, difficult to identify lexicography in a deterministic manner

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Conclusions

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- Evidence that departures by some respondent from a purely compensatory approach may have a very significant effect on findings in terms of heterogeneity
- Different interpretations of what leads to extreme sensitivities
  - ⋆ Could also include political voting, effects of fatigue, etc
- Significant scope for future work, including in labelled surveys
- Could obviously accommodate some of this behaviour through very flexible distributions (e.g. spikes at zero), but not very helpful for interpretation
  - ⋆ end aim should be to explain class allocation (attitudes may help), with a view to understanding reasons behind behavioural processes

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Second International Choice Modelling Conference

4 - 6 July 2011 | Oulton Hall | Yorkshire | UK

Jordan Louviere

Andrew Daly

Deadline for abstracts: 30 November 2010

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