Modeling Non-Consumptive Attributes in Choice Experiments

Klaus Moeltner
Virginia Tech

Johannes Reichl
Johannes Kepler University

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Definition of CRNCs

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Limited research / consensus on how to model them.

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Should / could **z** have *nonzero marginal utility* even in the absence of **x**?

Can we draw a general *working distinction* between $\mathbf{x}$ and $\mathbf{z}$?

Should / could $\mathbf{z}$ have *nonzero marginal utility* even in the absence of $\mathbf{x}$?

Could $\mathbf{z}$ be related to unobserved heterogeneity?

Bernheim, 2009

Generalized choice situation $G(X, d)$

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Generalized choice situation $G(X, d)$
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- exogenous feature of choice environment
- not relevant to social planner's policy evaluation
- elements that change when choice is delegated
- BUT "can be analyst-specific"

Salant & Rubinstein, 2008

Pair $(A, f) =$ *Extended choice problem*

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Observable information that is *irrelevant in the rational assessment* of the alternatives

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- labeling of "default alternative"

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Observable information that is *irrelevant in the rational assessment* of the alternatives

- orderings of choice options
- labeling of "default alternative"
- number of choice menus presented to individual

Potential candidates in CEs / NMV

- Presentation of information (text, visual, etc.)

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- Presentation of information (text, visual, etc.)
- Wording of food labeling ("contains" / "does not contain")
- Payment vehicle (tax, utility bill, etc.)
- Policy process / implementation (NGO, Gov. agency, etc.)
- Economic spillovers (secondary benefits to others)

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- observable to analyst

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- $\mathbf{z}$ can, in theory, affect utility irrespective of $\mathbf{x}$
- maximum econometric flexibility

Bateman et al., 2009

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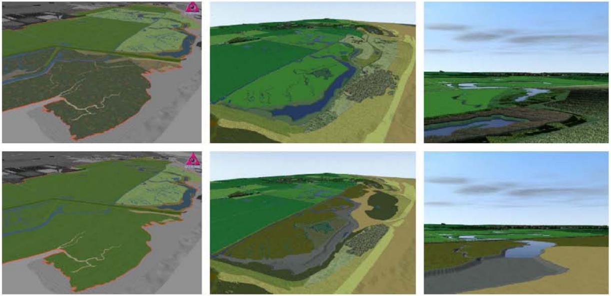

Fig. 1. VR visualisations of the status quo (upper row) and various alternative land use scenarios (lower row) from different viewing points.

Johnston & Duke, 2009

$\mathbf{x}$ = features of preserved farm land (size, current use, access)

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Table 2. Attributes and Levels for Choice Experiment Design

Attribute	Levels
Acres (4 levels)	1. 20 2. 60 3. 100 4. 200
Land type (5 levels)	1. Active farmland a. Nursery b. Food crop c. Dairy or livestock 2. Farmland (currently idle) 3. Forest
Policy technique and implementing agency (5 levels)	1. Preservation contracts a. By state b. By land trusts using block grants 2. Outright purchase a. By state b. By land trusts using block grants 3. Conservation zoning
Public access (3 levels)	1. No access allowed 2. Access for walking and biking 3. Access for hunting
Development risk (3 levels)	1. Development likely in less than 10 years if not preserved 2. Development likely in 10–30 years if not preserved 3. Development NOT likely within the next 30 years
Cost (6 levels)	1. \$5 2. \$15 3. \$30 4. \$50 5. \$100 6. \$200

Hu et al., 2005

$\mathbf{x}$ = flour type, brand (local, national), GMO content

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Table 1. Levels within each attribute of pre-packaged sliced bread

	Level 1	Level 2	Level 3	Level 4
Brand name	Store brand	National brand	—	—
Type of flour	White	Partial (60%) whole wheat	Whole wheat (100%)	Multigrain
Price (CND)	$0.99	$1.49	$2.49	$3.49
GM or not	GM ingredients present	GM ingredients absent	Not specified (as in the mixed labelling scenario)	—

Related Literature

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- Fiebig et al. (2010): Error scale vs. coefficient heterogeneity
- Torres et al. (2011): Different functional forms for IUF

Basic Setup

$$U_{i0}^{*} = \mathbf{x}_{i0}'\boldsymbol{\beta}_i^{*} + \gamma_i^{*} m_i + \epsilon_{i0}^{*}$$
$$U_{i1t}^{*} = \mathbf{x}_{i1t}'\boldsymbol{\beta}_i^{*} + \gamma_i^{*} \left(m_i + P_i\right) + \epsilon_{i1t}^{*}$$

Model in preference-space

$$U_{it}^{*} = U_{i1t}^{*} - U_{i0}^{*} = \mathbf{x}_{it}'\beta_i^{*} + \gamma_i^{*} P_i + \epsilon_{it}^{*} \quad \text{where}$$

$$\mathbf{x}_{it} = (\mathbf{x}_{i1t} - \mathbf{x}_{i0}) \text{ and } \epsilon_{it}^{*} = (\epsilon_{i1t}^{*} - \epsilon_{i0}^{*})$$

$$\epsilon_{it}^{*} \sim n\left(0, \sigma^2\right)$$

Model in WTP-space

$$U_{it} = \frac{U^*_{i1t}}{\gamma^*_i} = \mathbf{x}'_{it}\boldsymbol{\beta}_i + P_i + \epsilon_{it} \quad \text{where}$$

$$\boldsymbol{\beta}_i = \frac{\boldsymbol{\beta}^*_i}{\gamma^*_i} \text{ and } \epsilon_{it} = \frac{\epsilon^*_{it}}{\gamma^*_i} \quad \text{with}$$

$$\epsilon_{it} \sim n\left(0, \sigma^2_i\right) \text{ and } \sigma^2_i = \frac{\sigma^2}{\gamma^{*2}_i}$$

Advantages of WTP-space

- Direct priors for attribute-specific WTP ("*implicit prices*")

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- Gain in accuracy and robustness in hierarchical models (Sonnier et al., 2007)
- More intuitive interpretation of individual heterogeneity

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- Assume unobserved heterogeneity in preferences throughout
- $\mathbf{z}_i$ is respondent-specific (invariant w/in i)
- Must be linked to $\mathbf{x}_{it}$ (else drops out)

Model Overview

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  - Via increment
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Model S0

$$\boldsymbol{\beta}_i = \boldsymbol{\beta} + \boldsymbol{\delta}_i \quad \boldsymbol{\delta}_i \sim n(\mathbf{0}, \boldsymbol{\Sigma})$$

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$$E\left(\boldsymbol{\beta}_i\right) = \boldsymbol{\beta}$$
$$V\left(\boldsymbol{\beta}_i\right) = \boldsymbol{\Sigma}$$
$$E\left(\beta_{i,k}\right) = \beta_k$$
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Coefficient / expectation ratio

$$\frac{\beta_{i,k}}{E\left(\beta_{i,k}\right)} = \frac{\beta_k + \delta_{i,k}}{\beta_k} = 1 + \frac{\delta_{i,k}}{\beta_k}$$

Model S1a

$$\boldsymbol{\beta}_i = \boldsymbol{\beta} + \mathbf{A}\mathbf{z}_i + \boldsymbol{\delta}_i, \quad \text{where}$$

$$\mathbf{A} = \begin{Bmatrix} \alpha_{11} & \alpha_{12} & \dots & \alpha_{1l} \\ \alpha_{21} & \alpha_{22} & \dots & \alpha_{2l} \\ \vdots & \vdots & \ddots & \vdots \\ \alpha_{k1} & \alpha_{k2} & \dots & \alpha_{kl} \end{Bmatrix}$$

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$$E\left(\boldsymbol{\beta}_i\right) = \boldsymbol{\beta} + \mathbf{A}\mathbf{z}_i$$

$$V\left(\boldsymbol{\beta}_i\right) = \boldsymbol{\Sigma}$$

$$E\left(\beta_{i,k}\right) = \beta_k + \mathbf{z}_i'\boldsymbol{\alpha}_k$$

$$V\left(\beta_{i,k}\right) = \Sigma_{kk}$$

Model S1a, cont'd

Differential effect of binary CRNC

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Differential effect of binary CRNC

$$\beta_{i,k}|\,(z_{i,l}=1)-\beta_{i,k}|\,(z_{i,l}=0)=$$
$$\beta_k+\alpha_{kl}+\delta_{i,k}-(\beta_k+\delta_{i,k})=\alpha_{kl},\ \forall i$$

Model S1a, cont'd

Differential effect of binary CRNC

$$\beta_{i,k}|\left(z_{i,l}=1\right)-\beta_{i,k}|\left(z_{i,l}=0\right)=$$
$$\beta_k+\alpha_{kl}+\delta_{i,k}-\left(\beta_k+\delta_{i,k}\right)=\alpha_{kl},\ \forall i$$

Coefficient / expectation ratios

$$\begin{aligned}\frac{\beta_{i,k}|\left(z_{i,l}=0\right)}{E\left(\beta_{i,k}|\left(z_{i,l}=0\right)\right)}&=\frac{\beta_k+\delta_{i,k}}{\beta_k}=1+\frac{\delta_{i,k}}{\beta_k}\\ \frac{\beta_{i,k}|\left(z_{i,l}=1\right)}{E\left(\beta_{i,k}|\left(z_{i,k}=1\right)\right)}&=\frac{\beta_k+\alpha_{kl}+\delta_{i,k}}{\beta_k+\alpha_{kl}}=1+\frac{\delta_{i,k}}{\beta_k+\alpha_{kl}}\end{aligned}\qquad(1)$$

Model S1b

$$\boldsymbol{\beta}_i = (\mathbf{I} + \boldsymbol{\Lambda})\,\boldsymbol{\beta} + \boldsymbol{\delta}_i, \quad \text{where}$$

$$\boldsymbol{\Lambda} = \begin{Bmatrix} \mathbf{z}_i'\boldsymbol{\alpha}_1 & 0 & \dots & 0 \\ 0 & \mathbf{z}_i'\boldsymbol{\alpha}_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \mathbf{z}_i'\boldsymbol{\alpha}_k \end{Bmatrix},$$

$$\boldsymbol{\alpha}_k = \begin{Bmatrix} \alpha_{k1} & \alpha_{k2} & \dots & \alpha_{kl} \end{Bmatrix}',$$

Model S1b

$$\boldsymbol{\beta}_i = (\mathbf{I} + \boldsymbol{\Lambda})\,\boldsymbol{\beta} + \boldsymbol{\delta}_i, \quad \text{where}$$

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$$\boldsymbol{\alpha}_k = \left\{ \alpha_{k1} \quad \alpha_{k2} \quad \dots \quad \alpha_{kl} \right\}',$$

$$E(\boldsymbol{\beta}_i) = (\mathbf{I} + \boldsymbol{\Lambda})\,\boldsymbol{\beta}$$

$$V(\boldsymbol{\beta}_i) = \boldsymbol{\Sigma}$$

$$E(\beta_{i,k}) = \left(1 + \mathbf{z}_i'\boldsymbol{\alpha}_k\right)\beta_k$$

$$V(\beta_{i,k}) = \Sigma_{kk}$$

Model S1b, cont'd

Differential effect of binary CRNC

$$\beta_{i,k} | (z_{i,l} = 1) - \beta_{i,k} | (z_{i,l} = 0) =$$
$$(1 + \alpha_{kl})\, \beta_k + \delta_{i,k} - (\beta_k + \delta_{i,k}) = \alpha_{kl} \beta_k, \; \forall i$$

Model S1b, cont'd

Differential effect of binary CRNC

$$\beta_{i,k}|\left(z_{i,l}=1\right)-\beta_{i,k}|\left(z_{i,l}=0\right)=$$
$$\left(1+\alpha_{kl}\right)\beta_k+\delta_{i,k}-\left(\beta_k+\delta_{i,k}\right)=\alpha_{kl}\beta_k,\ \forall i$$

Coefficient / expectation ratios

$$\frac{\beta_{i,k}|z_{i,l}=0}{E\left(\beta_{i,k}|z_{i,l}=0\right)}=\frac{\beta_k+\delta_{i,k}}{\beta_k}=1+\frac{\delta_{i,k}}{\beta_k}$$
$$\frac{\beta_{i,k}|z_{i,l}=1}{E\left(\beta_{i,k}|z_{i,k}=1\right)}=\frac{\left(1+\alpha_{kl}\right)\beta_k+\delta_{i,k}}{\left(1+\alpha_{kl}\right)\beta_k}=1+\frac{\delta_{i,k}}{\left(1+\alpha_{kl}\right)\beta_k}$$

Model S2a

$$\boldsymbol{\beta}_i = \boldsymbol{\beta} + \boldsymbol{\Gamma}\boldsymbol{\delta}_i, \quad \text{where}$$

$$\boldsymbol{\Gamma} = \begin{Bmatrix} \mathbf{z}_i'\gamma_1 & 0 & \dots & 0 \\ 0 & \mathbf{z}_i'\gamma_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \mathbf{z}_i'\gamma_k \end{Bmatrix},$$

$$\boldsymbol{\gamma}_k = \begin{Bmatrix} \gamma_{k1} & \gamma_{k2} & \dots & \gamma_{kl} \end{Bmatrix}',$$

Model S2a

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$$E(\boldsymbol{\beta}_i) = \boldsymbol{\beta}$$

$$V(\boldsymbol{\beta}_i) = \boldsymbol{\Gamma\Sigma\Gamma}'$$

$$E(\beta_{i,k}) = \beta_k$$

$$V(\beta_{i,k}) = (\mathbf{z}_i'\gamma_k)^2 \Sigma_{kk}$$

Model S2a, cont'd

Differential effect of binary CRNC

$$\beta_{i,k}|\,(z_{i,l} = 1) - \beta_{i,k}|\,(z_{i,l} = 0) = \\ \beta_k + \gamma_{kl}\delta_{i,k} - \beta_k = \gamma_{kl}\delta_{i,k}$$

Model S2a, cont'd

Differential effect of binary CRNC

$$\beta_{i,k}|\left(z_{i,l}=1\right)-\beta_{i,k}|\left(z_{i,l}=0\right)= \\ \beta_k+\gamma_{kl}\delta_{i,k}-\beta_k=\gamma_{kl}\delta_{i,k}$$

Coefficient / expectation ratios

$$\frac{\beta_{i,k}|z_{i,l}=0}{E\left(\beta_{i,k}|z_{i,l}=0\right)}=\frac{\beta_k}{\beta_k}=1$$
$$\frac{\beta_{i,k}|z_{i,l}=1}{E\left(\beta_{i,k}|z_{i,k}=1\right)}=1+\frac{\gamma_{kl}\delta_{i,k}}{\beta_k}$$

Model S2b

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Model S2b

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$$E(\boldsymbol{\beta}_i) = \boldsymbol{\beta}$$
$$V(\boldsymbol{\beta}_i) = (\mathbf{I} + \boldsymbol{\Gamma})\,\boldsymbol{\Sigma}\,(\mathbf{I} + \boldsymbol{\Gamma})'$$
$$E(\beta_{i,k}) = \beta_k$$
$$V(\beta_{i,k}) = \left(1 + \mathbf{z}_i'\gamma_k\right)^2 \Sigma_{kk}$$

Model S2b, cont'd

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Coefficient / expectation ratios

$$\frac{\beta_{i,k}|z_{i,l}=0}{E\left(\beta_{i,k}|z_{i,l}=0\right)}=\frac{\beta_k}{\beta_k}=1$$
$$\frac{\beta_{i,k}|z_{i,l}=1}{E\left(\beta_{i,k}|z_{i,k}=1\right)}=1+\frac{\left(1+\gamma_{kl}\right)\delta_{i,k}}{\beta_k}$$

Model S3aa

$$\beta_i = \beta + \mathbf{A}\mathbf{z}_i + \mathbf{\Gamma}\delta_i$$

Model S3aa

$$\boldsymbol{\beta}_i = \boldsymbol{\beta} + \mathbf{A}\mathbf{z}_i + \boldsymbol{\Gamma}\boldsymbol{\delta}_i$$

$$E\left(\boldsymbol{\beta}_i\right) = \boldsymbol{\beta} + \mathbf{A}\mathbf{z}_i$$
$$V\left(\boldsymbol{\beta}_i\right) = \boldsymbol{\Gamma}\boldsymbol{\Sigma}\boldsymbol{\Gamma}'$$
$$E\left(\beta_{i,k}\right) = \beta_k + \mathbf{z}_i'\boldsymbol{\alpha}_k$$
$$V\left(\beta_{i,k}\right) = \left(\mathbf{z}_i'\gamma_k\right)^2 \Sigma_{kk}$$

Model S3aa, cont'd

Differential effect of binary CRNC

$$\beta_{i,k}|\,(z_{i,l}=1)-\beta_{i,k}|\,(z_{i,l}=0)=$$
$$\beta_k+\alpha_{kl}+\gamma_{kl}\delta_{i,k}-\beta_k=\alpha_{kl}+\gamma_{kl}\delta_{i,k}$$

Model S3aa, cont'd

Differential effect of binary CRNC

$$\beta_{i,k}|\,(z_{i,l}=1)-\beta_{i,k}|\,(z_{i,l}=0)=$$
$$\beta_k+\alpha_{kl}+\gamma_{kl}\delta_{i,k}-\beta_k=\alpha_{kl}+\gamma_{kl}\delta_{i,k}$$

Coefficient / expectation ratios

$$\frac{\beta_{i,k}|z_{i,l}=0}{E\left(\beta_{i,k}|z_{i,l}=0\right)}=\frac{\beta_k}{\beta_k}=1$$
$$\frac{\beta_{i,k}|z_{i,l}=1}{E\left(\beta_{i,k}|z_{i,k}=1\right)}=1+\frac{\gamma_{kl}\delta_{i,k}}{\beta_k+\alpha_{kl}}$$

Model S3ba

$$\boldsymbol{\beta}_i = (\mathbf{I} + \mathbf{\Lambda})\,\boldsymbol{\beta} + \mathbf{\Gamma}\boldsymbol{\delta}_i$$

Model S3ba

$$\boldsymbol{\beta}_i = (\mathbf{I} + \boldsymbol{\Lambda})\,\boldsymbol{\beta} + \boldsymbol{\Gamma}\boldsymbol{\delta}_i$$

$$E(\boldsymbol{\beta}_i) = (\mathbf{I} + \boldsymbol{\Lambda})\,\boldsymbol{\beta}$$
$$V(\boldsymbol{\beta}_i) = \boldsymbol{\Gamma}\boldsymbol{\Sigma}\boldsymbol{\Gamma}'$$
$$E(\beta_{i,k}) = \left(1 + \mathbf{z}_i'\boldsymbol{\alpha}_k\right)\beta_k$$
$$V(\beta_{i,k}) = \left(\mathbf{z}_i'\gamma_k\right)^2 \Sigma_{kk}$$

Model S3ba, cont'd

Differential effect of binary CRNC

$$\beta_{i,k} | (z_{i,l} = 1) - \beta_{i,k} | (z_{i,l} = 0) =$$
$$(1 + \alpha_{kl}) \beta_k + \gamma_{kl} \delta_{i,k} - \beta_k = \alpha_{kl} \beta_k + \gamma_{kl} \delta_{i,k}$$

Model S3ba, cont'd

Differential effect of binary CRNC

$$\beta_{i,k}|\left(z_{i,l}=1\right)-\beta_{i,k}|\left(z_{i,l}=0\right)=$$
$$\left(1+\alpha_{kl}\right)\beta_k+\gamma_{kl}\delta_{i,k}-\beta_k=\alpha_{kl}\beta_k+\gamma_{kl}\delta_{i,k}$$

Coefficient / expectation ratios

$$\frac{\beta_{i,k}|z_{i,l}=0}{E\left(\beta_{i,k}|z_{i,l}=0\right)}=\frac{\beta_k}{\beta_k}=1$$
$$\frac{\beta_{i,k}|z_{i,l}=1}{E\left(\beta_{i,k}|z_{i,k}=1\right)}=1+\frac{\gamma_{kl}\delta_{i,k}}{\left(1+\alpha_{kl}\right)\beta_k}$$

Model S3ab

$$\beta_i = \beta + \mathbf{A}\mathbf{z}_i + (\mathbf{I} + \mathbf{\Gamma})\,\delta_i$$

Model S3ab

$$\boldsymbol{\beta}_i = \boldsymbol{\beta} + \mathbf{A}\mathbf{z}_i + (\mathbf{I} + \boldsymbol{\Gamma})\,\boldsymbol{\delta}_i$$

$$E(\boldsymbol{\beta}_i) = \boldsymbol{\beta} + \mathbf{A}\mathbf{z}_i$$
$$V(\boldsymbol{\beta}_i) = (\mathbf{I} + \boldsymbol{\Gamma})\,\boldsymbol{\Sigma}\,(\mathbf{I} + \boldsymbol{\Gamma})'$$
$$E(\beta_{i,k}) = \beta_k + \mathbf{z}_i'\boldsymbol{\alpha}_k$$
$$V(\beta_{i,k}) = \left(1 + \mathbf{z}_i'\gamma_k\right)^2 \Sigma_{kk}$$

Model S3ab, cont'd

Differential effect of binary CRNC

$$\beta_{i,k} | (z_{i,l} = 1) - \beta_{i,k} | (z_{i,l} = 0) =$$
$$\beta_k + \alpha_{kl} + (1 + \gamma_{kl})\, \delta_{ik} - (\beta_k + \delta_{i,k}) = \alpha_{kl} + \gamma_{kl}\delta_{i,k}$$

Model S3ab, cont'd

Differential effect of binary CRNC

$$\beta_{i,k}|\left(z_{i,l}=1\right)-\beta_{i,k}|\left(z_{i,l}=0\right)=$$
$$\beta_k+\alpha_{kl}+\left(1+\gamma_{kl}\right)\delta_{ik}-\left(\beta_k+\delta_{i,k}\right)=\alpha_{kl}+\gamma_{kl}\delta_{i,k}$$

Coefficient / expectation ratios

$$\frac{\beta_{i,k}|\left(z_{i,l}=0\right)}{E\left(\beta_{i,k}|\left(z_{i,l}=0\right)\right)}=\frac{\beta_k+\delta_{i,k}}{\beta_k}=1+\frac{\delta_{ik}}{\beta_k}$$
$$\frac{\beta_{i,k}|\left(z_{i,l}=1\right)}{E\left(\beta_{i,k}|\left(z_{i,k}=1\right)\right)}=\frac{\left(\beta_k+\alpha_{kl}\right)+\left(1+\gamma_{kl}\right)\delta_{ik}}{\beta_k+\alpha_{kl}}=1+\frac{\left(1+\gamma_{kl}\right)\delta_{ik}}{\beta_k+\alpha_{kl}}$$

Model S3bb

$$\beta_i = (\mathbf{I} + \mathbf{\Lambda})\,\beta + (\mathbf{I} + \mathbf{\Gamma})\,\delta_i$$

Model S3bb

$$\boldsymbol{\beta}_i = (\mathbf{I} + \boldsymbol{\Lambda})\, \boldsymbol{\beta} + (\mathbf{I} + \boldsymbol{\Gamma})\, \boldsymbol{\delta}_i$$

$$E\left(\boldsymbol{\beta}_i\right) = (\mathbf{I} + \boldsymbol{\Lambda})\, \boldsymbol{\beta}$$
$$V\left(\boldsymbol{\beta}_i\right) = (\mathbf{I} + \boldsymbol{\Gamma})\, \boldsymbol{\Sigma}\, (\mathbf{I} + \boldsymbol{\Gamma})'$$
$$E\left(\beta_{i,k}\right) = \left(1 + \mathbf{z}_i' \boldsymbol{\alpha}_k\right) \beta_k$$
$$V\left(\beta_{i,k}\right) = \left(1 + \mathbf{z}_i' \gamma_k\right)^2 \Sigma_{kk}$$

Model S3bb, cont'd

Differential effect of binary CRNC

$$\beta_{i,k}|\,(z_{i,l}=1)-\beta_{i,k}|\,(z_{i,l}=0)=$$
$$(1+\alpha_{kl})\,\beta_k+(1+\gamma_{kl})\,\delta_{ik}-(\beta_k+\delta_{i,k})= \quad \alpha_{kl}\beta_k+\gamma_{kl}\delta_{i,k}$$

Model S3bb, cont'd

Differential effect of binary CRNC

$$\beta_{i,k}|\left(z_{i,l}=1\right)-\beta_{i,k}|\left(z_{i,l}=0\right)=$$
$$\left(1+\alpha_{kl}\right)\beta_k+\left(1+\gamma_{kl}\right)\delta_{ik}-\left(\beta_k+\delta_{i,k}\right)= \quad \alpha_{kl}\beta_k+\gamma_{kl}\delta_{i,k}$$

Coefficient / expectation ratios

$$\frac{\beta_{i,k}|\left(z_{i,l}=0\right)}{E\left(\beta_{i,k}|\left(z_{i,l}=0\right)\right)}=\frac{\beta_k+\delta_{i,k}}{\beta_k}=1+\frac{\delta_{ik}}{\beta_k}$$
$$\frac{\beta_{i,k}|\left(z_{i,l}=1\right)}{E\left(\beta_{i,k}|\left(z_{i,k}=1\right)\right)}=\frac{\left(1+\alpha_{kl}\right)\beta_k+\left(1+\gamma_{kl}\right)\delta_{ik}}{\left(1+\alpha_{kl}\right)\beta_k}=1+\frac{\left(1+\gamma_{kl}\right)\delta_{ik}}{\left(1+\alpha_{kl}\right)\beta_k}$$

Estimation

Hierarchical structure of model:

Estimation

Hierarchical structure of model:

$$\boldsymbol{\beta}_i \sim n\left(f\left(\boldsymbol{\beta}, \mathbf{A}, \mathbf{z}_i\right), g\left(\boldsymbol{\Sigma}, \boldsymbol{\Gamma}, \mathbf{z}_i\right)\right)$$

$$\sigma_i^2 \sim ig\left(\nu_0, \tau\right)$$

$$\boldsymbol{\beta} \sim n\left(\boldsymbol{\mu}_{\boldsymbol{\beta},0}, \mathbf{V}_{\boldsymbol{\beta},0}\right)$$

$$\mathbf{A} \sim n\left(\boldsymbol{\mu}_{\mathbf{A},0}, \mathbf{V}_{\mathbf{A},0}\right)$$

$$\boldsymbol{\Gamma} \sim n\left(\boldsymbol{\mu}_{\boldsymbol{\Gamma},0}, \mathbf{V}_{\boldsymbol{\Gamma},0}\right)$$

$$\tau \sim gam\left(\eta_0, \psi_0\right)$$

Joint posterior distribution (example models S3):

Joint posterior distribution (example models S3):

$$p\left(\beta, \mathbf{\Sigma}, \mathbf{A}, \mathbf{\Gamma}, \tau, \{\beta_i\}, \left\{\sigma_i^2\right\}, \mathbf{U}|\mathbf{y}, \mathbf{X}, \mathbf{Z}\right) \propto$$
$$p\left(\beta|\mathbf{\Sigma}\right) p\left(\mathbf{\Sigma}\right) p\left(\mathbf{A}\right) p\left(\mathbf{\Gamma}\right) p\left(\tau\right) *$$
$$p\left(\{\beta_i\}|\beta, \mathbf{\Sigma}, \mathbf{A}, \mathbf{\Gamma}, \mathbf{Z}\right) p\left(\left\{\sigma_i^2\right\}|\tau\right) *$$
$$p\left(\mathbf{U}|\{\beta_i\}, \left\{\sigma_i^2\right\}, \mathbf{X}\right) p\left(\mathbf{y}|\mathbf{U}\right)$$

Joint posterior distribution (example models S3):

$$p\left(\boldsymbol{\beta}, \boldsymbol{\Sigma}, \mathbf{A}, \boldsymbol{\Gamma}, \tau, \{\boldsymbol{\beta}_i\}, \left\{\sigma_i^2\right\}, \mathbf{U} | \mathbf{y}, \mathbf{X}, \mathbf{Z}\right) \propto$$
$$p(\boldsymbol{\beta}|\boldsymbol{\Sigma})\, p(\boldsymbol{\Sigma})\, p(\mathbf{A})\, p(\boldsymbol{\Gamma})\, p(\tau) *$$
$$p(\{\boldsymbol{\beta}_i\}|\boldsymbol{\beta}, \boldsymbol{\Sigma}, \mathbf{A}, \boldsymbol{\Gamma}, \mathbf{Z})\, p\left(\left\{\sigma_i^2\right\}|\tau\right) *$$
$$p\left(\mathbf{U}|\{\boldsymbol{\beta}_i\}, \left\{\sigma_i^2\right\}, \mathbf{X}\right) p(\mathbf{y}|\mathbf{U})$$

$\rightarrow$ Gibbs Sampler

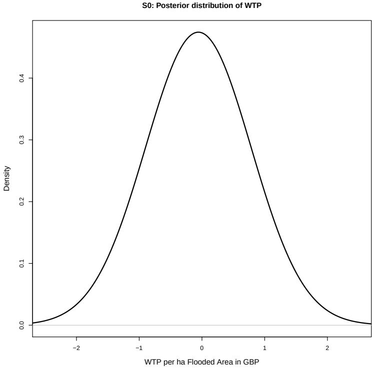
Results

Model Comparison

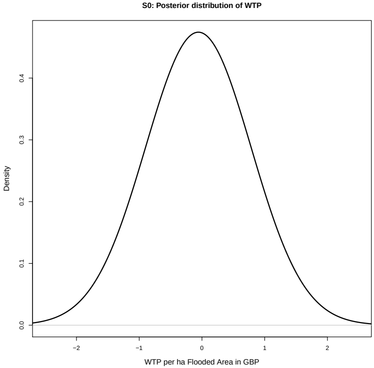
Model	MAD	Hit Rate
S0	0.263	0.757
S1a	0.228	0.790
S2b	0.220	0.783
S3a	0.216	0.786
S3b	0.226	0.778

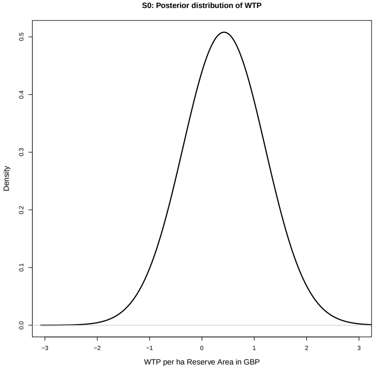
Model S0

Model S0


S0: Posterior distribution of WTP
Density
0.0
0.1
0.2
0.3
0.4
−2
−1
0
1
2
WTP per ha Flooded Area in GBP

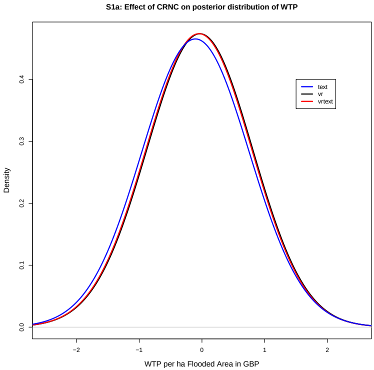
Model S0


S0: Posterior distribution of WTP
Density
0.0
0.1
0.2
0.3
0.4
−2
−1
0
1
2
WTP per ha Flooded Area in GBP

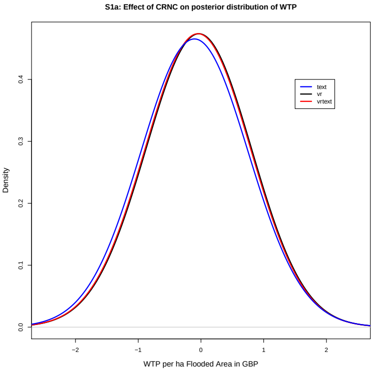

S0: Posterior distribution of WTP
Density
0.0
0.1
0.2
0.3
0.4
0.5
−3
−2
−1
0
1
2
3
WTP per ha Reserve Area in GBP

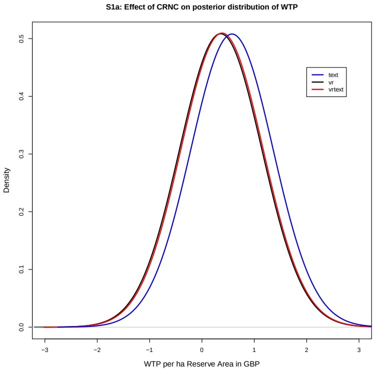
Model S1a

Model S1a


S1a: Effect of CRNC on posterior distribution of WTP
text
vr
vrtext
Density
0.0
0.1
0.2
0.3
0.4
−2
−1
0
1
2
WTP per ha Flooded Area in GBP

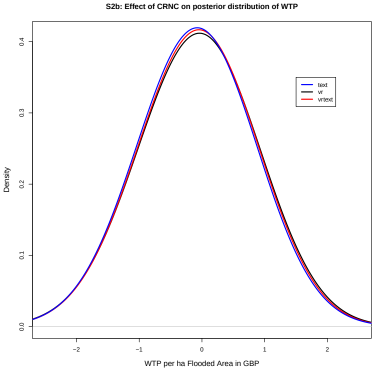
Model S1a


S1a: Effect of CRNC on posterior distribution of WTP
Density
0.0
0.1
0.2
0.3
0.4
−2
−1
0
1
2
WTP per ha Flooded Area in GBP
text
vr
vrtext

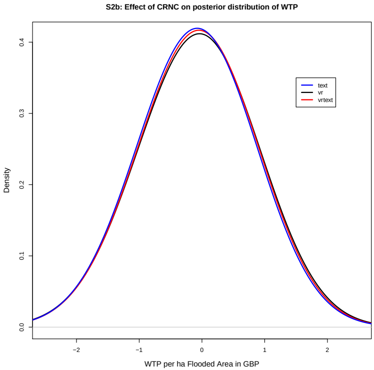

S1a: Effect of CRNC on posterior distribution of WTP
Density
0.0
0.1
0.2
0.3
0.4
0.5
−3
−2
−1
0
1
2
3
WTP per ha Reserve Area in GBP
text
vr
vrtext

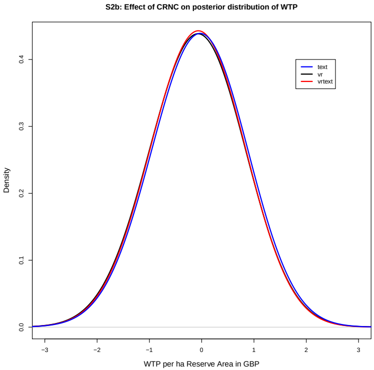
Model S2b

Model S2b


S2b: Effect of CRNC on posterior distribution of WTP
Density
WTP per ha Flooded Area in GBP
text
vr
vrtext
0.0
0.1
0.2
0.3
0.4
−2
−1
0
1
2

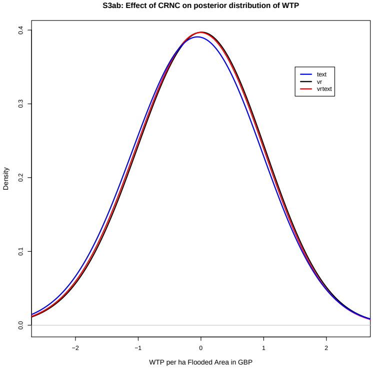
Model S2b


S2b: Effect of CRNC on posterior distribution of WTP
Density
WTP per ha Flooded Area in GBP
text
vr
vrtext
0.0
0.1
0.2
0.3
0.4
−2
−1
0
1
2

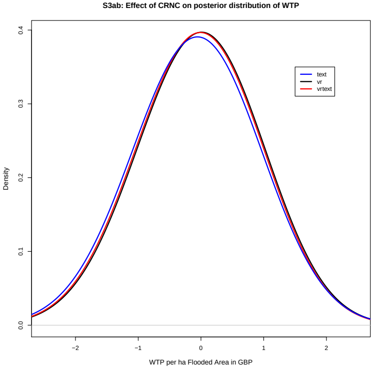

S2b: Effect of CRNC on posterior distribution of WTP
Density
WTP per ha Reserve Area in GBP
text
vr
vrtext
0.0
0.1
0.2
0.3
0.4
−3
−2
−1
0
1
2
3

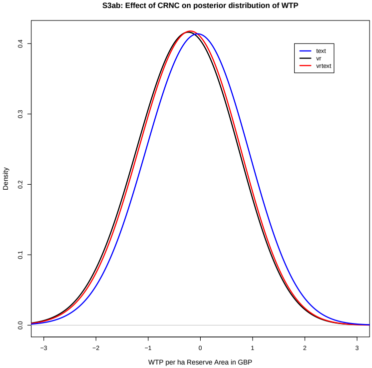
Model S3ab

Model S3ab


S3ab: Effect of CRNC on posterior distribution of WTP
Density
WTP per ha Flooded Area in GBP
text
vr
vrtext
0.0
0.1
0.2
0.3
0.4
−2
−1
0
1
2

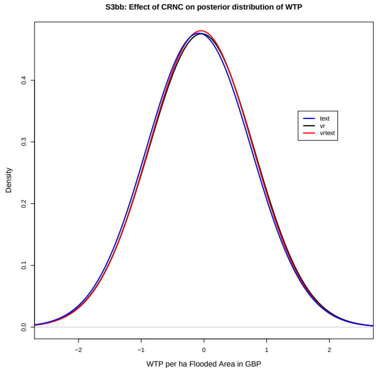
Model S3ab


S3ab: Effect of CRNC on posterior distribution of WTP
Density
text
vr
vrtext
WTP per ha Flooded Area in GBP

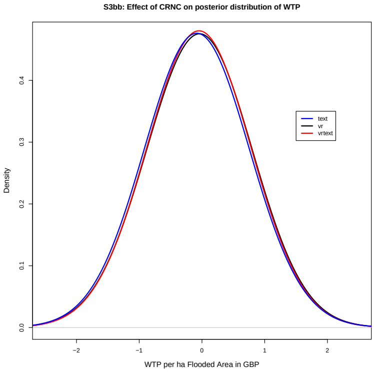

S3ab: Effect of CRNC on posterior distribution of WTP
Density
text
vr
vrtext
WTP per ha Reserve Area in GBP

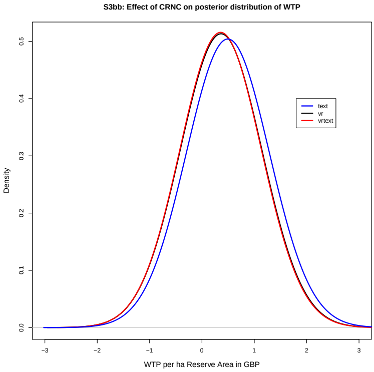
Model S3bb

Model S3bb

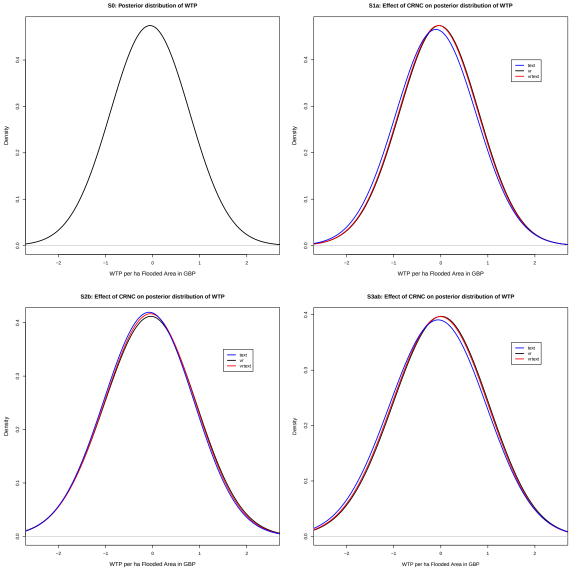

S3bb: Effect of CRNC on posterior distribution of WTP
Density
0.0
0.1
0.2
0.3
0.4
−2
−1
0
1
2
WTP per ha Flooded Area in GBP
text
vr
vrtext

Model S3bb

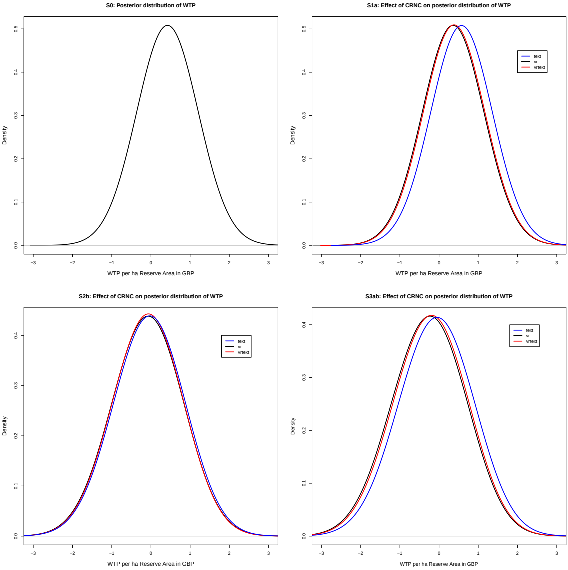

S3bb: Effect of CRNC on posterior distribution of WTP
Density
0.0
0.1
0.2
0.3
0.4
−2
−1
0
1
2
WTP per ha Flooded Area in GBP
text
vr
vrtext


S3bb: Effect of CRNC on posterior distribution of WTP
Density
0.0
0.1
0.2
0.3
0.4
0.5
−3
−2
−1
0
1
2
3
WTP per ha Reserve Area in GBP
text
vr
vrtext

flooded


S0: Posterior distribution of WTP
S1a: Effect of CRNC on posterior distribution of WTP
S2b: Effect of CRNC on posterior distribution of WTP
S3ab: Effect of CRNC on posterior distribution of WTP
Density
WTP per ha Flooded Area in GBP
text
vr
vrtext

reserve


S0: Posterior distribution of WTP
S1a: Effect of CRNC on posterior distribution of WTP
S2b: Effect of CRNC on posterior distribution of WTP
S3ab: Effect of CRNC on posterior distribution of WTP
Density
WTP per ha Reserve Area in GBP
text
vr
vrtext

Next steps

- Compute marginal likelihood and posterior model probabilities

Next steps

- Compute marginal likelihood and posterior model probabilities
- Examine restrictions on $\mathbf{A}, \mathbf{\Gamma}$

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- Derive model-averaged results

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THANK YOU!