"Contingent valuation under scale heterogeneity and distributional incidence considerations of policies to reduce the risk of moose-vehicle collisions in Newfoundland"

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Introduction

- Moose provide many benefits in Newfoundland
- However, high densities result also in many moose-vehicle accidents (MVCs)
- About 600-800 MVC each year, with an average of two fatalities per year

Introduction

- Policy issue: how much is a risk reduction worth?
- Is it worth the cost?
- Does the decision depend on which criterion is used to share the cost and to aggregate individual preferences?

Introduction

- We estimated the ***willingness to pay*** (WTP) for reductions of the risk of a moose-vehicle accident
- I will discuss several intricacies of this type of nonmarket valuation exercise

Introduction

- For example, we have addressed the possibility of scale heterogeneity in the distribution of WTP among groups of individuals
- And we have considered the difficulties associated with using ***double-bounded dichotomous choice*** (DBDC) models
- Our results suggest that, while the most complete model, the estimated WTP is fairly similar to the one estimated using simpler models

Introduction

- Finally, we discuss the decision about whether a risk reduction strategy would be deemed desirable

The policy problem

MVC mitigation strategies?

- educational campaigns
- warning signs
- wildlife warning reflectors or mirrors
- wildlife fences, animal detection systems
- hunting quotas…

Fencing is often advocated as the most effective and efficient strategy

The policy problem

- However, we know only about the costs of installing and maintaining fences on the highways
- Are fences worth the expense?
- What are the full economic benefits of reducing MVC risk?
- Estimate of the WTP for a reduction of the MVC <u>death</u> and <u>injury</u> risks

The policy problem

- When do we decide the risk reduction is worthwhile?
- When aggregate benefit exceeds aggregate cost?
- This is the notion of ***efficiency*** based on the ***Hicks-Kaldor*** criterion
- The ***<u>Potential</u> Pareto Principle***

The policy problem

- Or do we care about distributional aspects?
- How should the costs be distributed?
- Does it matter for the result of a referendum? (this is "one person = one vote" rather than "$1 = 1 vote")

The valuation exercise

- Estimation of WTP for reducing the risk of MVCs in Newfoundland
- ***Contingent valuation method*** (CVM)
- ***Double-bounded dichotomous-choice*** (DBDC) questions

The valuation exercise

- ***Dichotomous-choice*** (yes/ no) questions are more intuitive than direct WTP questions
- But statistically inefficient…
- DBDC questions help with efficiency but may induce ***question-effects*** that bias WTP estimates, usually downwards

The valuation exercise: issues

- individuals are very imprecise when stating their preferences about risk reductions
- well-documented difficulties to understand small (changes in) probabilities
- CVM results, especially about risk reductions, are notoriously ***insensitive to scope*** … which makes them truly suspect…
- WTP should theoretically be ***near-proportional*** to scope

The valuation exercise: issues

- Could *being good at math* help?
- Four math questions to develop ***mathscore***
- Should we put more faith on the responses of those with higher ***mathscore*** values?
- Is that fair?

The valuation exercise: issues

- constructed quasi-continuous measure of scope (***diffM*** for the size of reduction of death risk and ***diffI*** for the size of reduction of injury risk)
- From ***baseline risk*** (death and injury) elicited from the respondent (subjective) or provided by us (objective) and a randomized proportion of risk reduction (2, 4, 6)

The valuation exercise: issues

- Do we ask for the WTP for the risk reduction strategy (a ***public good***) using a private good analogy in the hypothetical valuation scenario?
- Does it make a difference?
- Our survey design considered this

The valuation exercise: issues

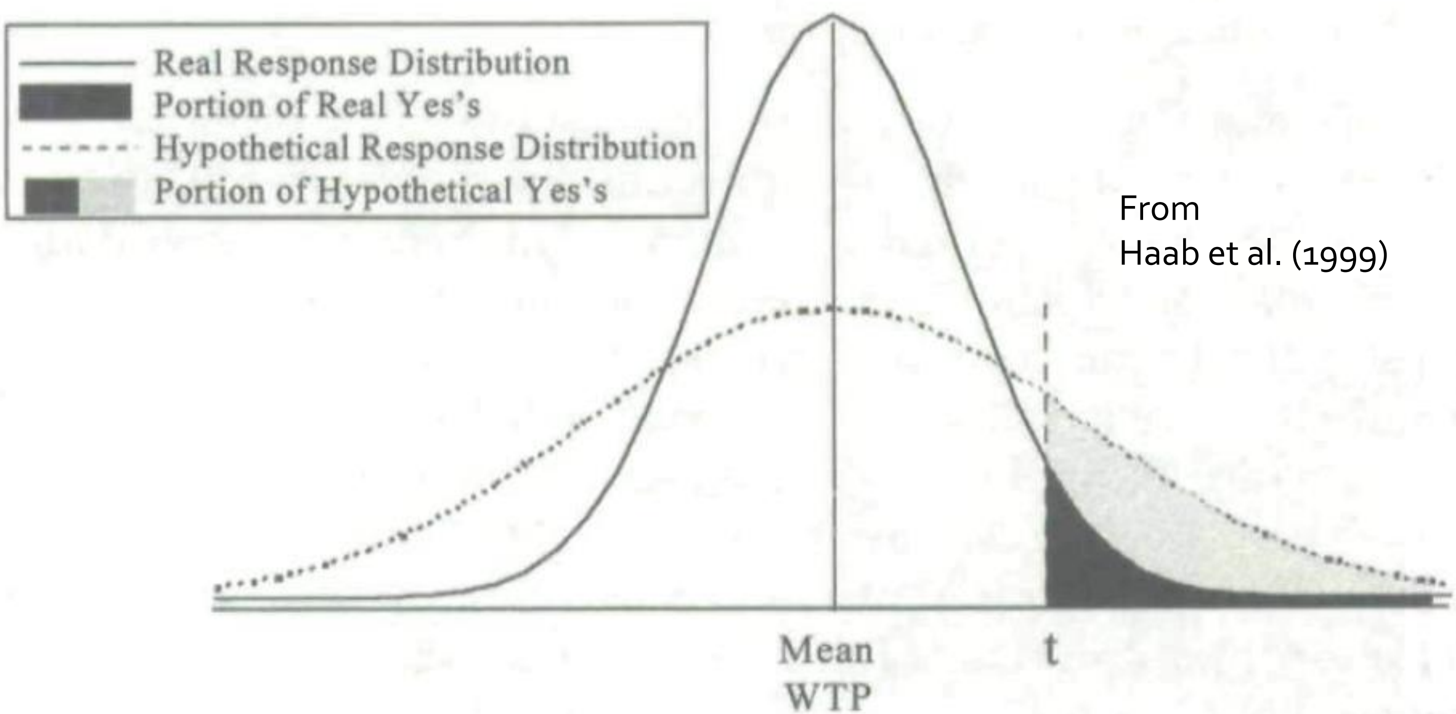
- Major issue: CVM estimates are susceptible to ***hypothetical bias*** in general…
- Might considering the degree of response certainty help?
- We collected ***howsure*** (a ***numerical certainty scale***) from a follow-up to the payment question

Scale heterogeneity

- Often assumed that all groups of individuals have more or less the same *spread* in the distribution of their WTP
- This is something to be careful about if we use limited dependent variable models (such as logits/probits)
- These models usually only provide estimates that are a ratio of the (unobservable) slope coefficient and the (also unobservable) scale parameter

Scale heterogeneity (heteroskedasticity)

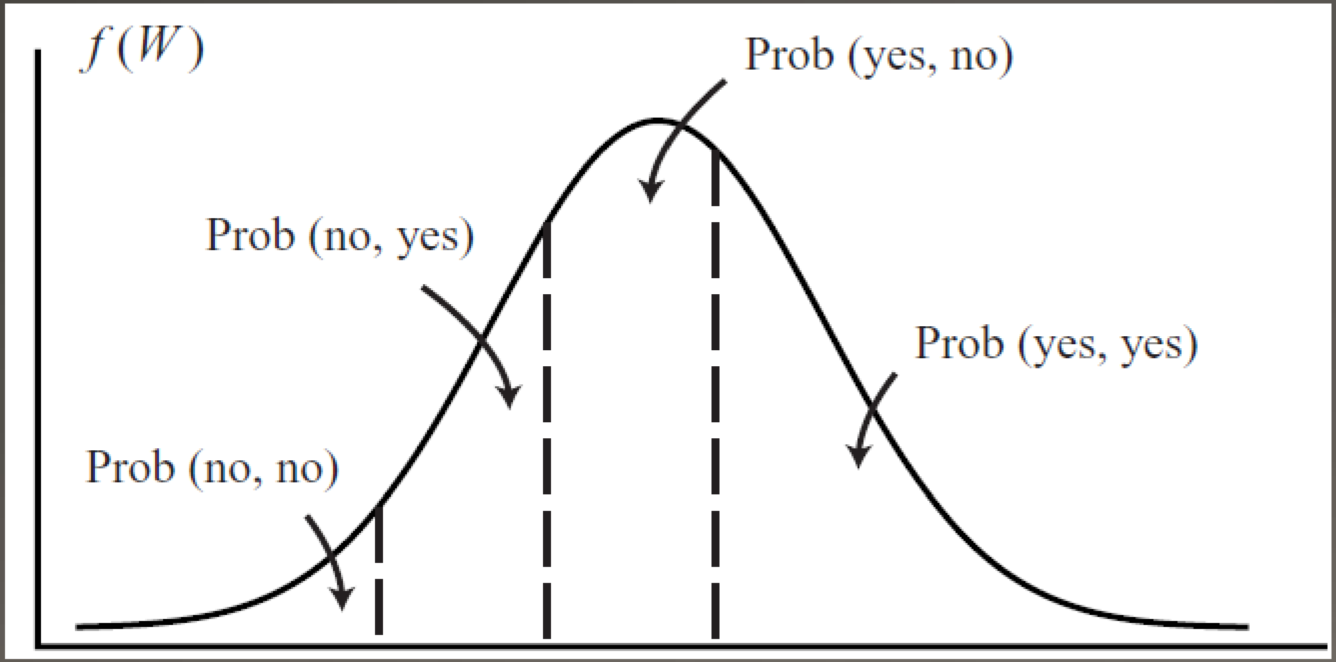
FIG. 1.—Potential response rates for hypothetical and real experiments with different scales.



From
Haab et al. (1999)

Scale heterogeneity (heteroskedasticity)

- Similarly, in the double bounded case:



Distribution of WTP

Scale heterogeneity

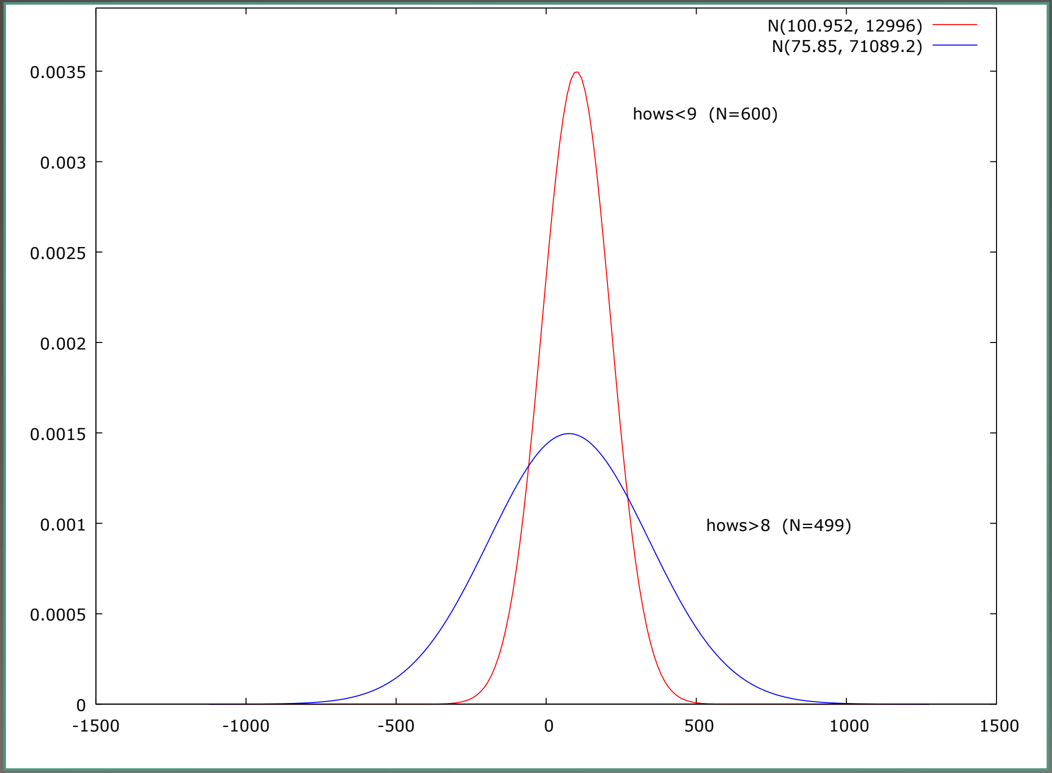
Could modelling this type of ***heteroskedasticity*** make a difference…?

- On size of estimated mean WTP?
- On importance and influence of question effects?
- On sensitivity to scope?

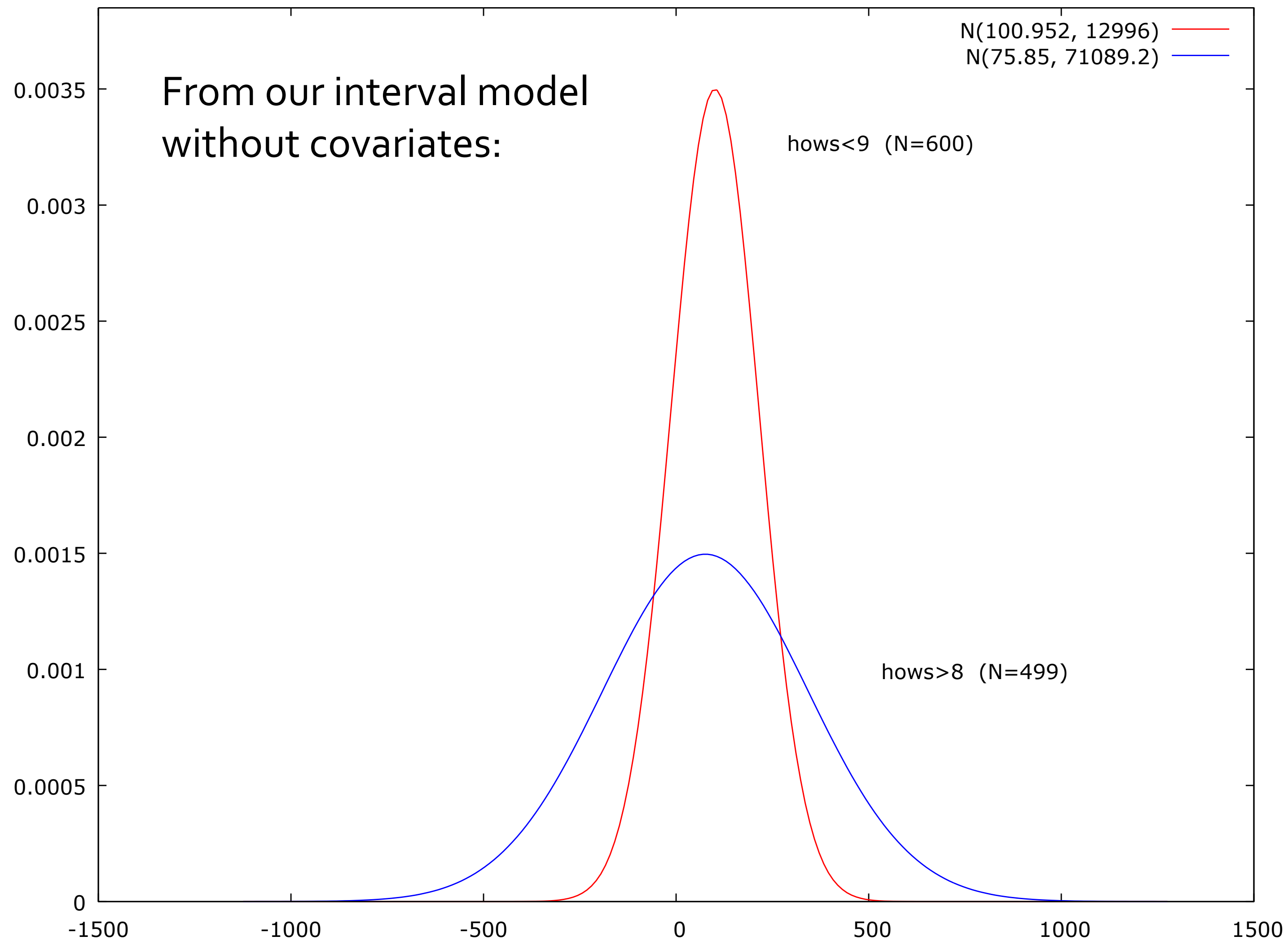
Scale heterogeneity

- Could the variance (*scale*) depend on level of response certainty (***howsure***)?

From our interval model without covariates:



Scale heterogeneity



The survey

Table 3: Percent distribution of response patterns by initial bid (CAD $), without protests (N=1417)

Initial bid	No-No	No-Yes	Yes-No	Yes-Yes	Total
$15	23.35	6.09	17.26	53.3	100
$30	25.32	12.99	21.43	40.26	100
$45	25.97	6.08	24.86	43.09	100
$60	32.18	11.88	24.26	31.68	100
$75	34.3	8.14	20.35	37.21	100
$100	30.56	9.44	25.00	35.00	100
$120	34.33	11.94	26.87	26.87	100
$150	44.37	11.97	24.65	19.01	100
$200	35.48	12.9	22.58	29.03	100
$250	12.5	16.67	45.83	25.00	100
Total	30.63	9.81	23.29	36.27	100

The survey

Table 1: Distribution of respondents by survey version (sample sizes in brackets include protest responses).

	N	Mitigation Strategy	Comprehensive*	Fences mentioned**
Version A	209 (235)	Safety device	1	Not applicable
Version B	212 (240)	Safety device	0	Not applicable
Version C	189 (233)	Public policy	1	YES
Version D	171 (224)	Public policy	0	NO
Version E	182 (225)	Safety device	0	Not applicable
		Public policy	0	NO
Version F	143 (199)	Safety device	1***	Not applicable
		Public policy	1	YES
Total	1,106 (1,356)			

*Mitigation strategy would reduce both injury and death risks.

**Fencing was explicitly mentioned as the specific public strategy to reduce MVCs.

***Safety device in Version F prevents collision rather than just risk of death/injury

Methodology

Analysis of double bound

- Single Bound (SB) using only first question
- Question effects
- A Shift
- (Heterogeneous) anchoring

- Response uncertainty

Allowing for scale heterogeneity

- Response certainty as a measure of scale heterogeneity (1-10 NCS)
- Effects on WTP
- Effects of the influence of question effects

The model

Heterogenous anchoring parameter

Shift parameter

Variable scale parameter

$$
\begin{aligned}
Pr(nn) &= \Phi\left(\left[\frac{\text{secondbid}_\text{i} - \gamma_i \text{firstbid}_\text{i} - \delta}{1-\gamma_i} - x_i\beta\right]/\sigma_i\right) \\
Pr(ny) &= \Phi\left(\left[\text{firstbid}_\text{i} - x_i\beta\right]/\sigma_i\right) - \Phi\left(\left[\frac{\text{secondbid}_\text{i} - \gamma_i \text{firstbid}_\text{i} - \delta}{1-\gamma_i} - x_i\beta\right]/\sigma_i\right) \\
Pr(yn) &= \Phi\left(\left[\frac{\text{secondbid}_\text{i} - \gamma_i \text{firstbid}_\text{i} - \delta}{1-\gamma_i} - x_i\beta\right]/\sigma_i\right) - \Phi\left(\left[\text{firstbid}_\text{i} - x_i\beta\right]/\sigma_i\right) \\
Pr(yy) &= 1 - \Phi\left(\left[\frac{\text{secondbid}_\text{i} - \gamma_i \text{firstbid}_\text{i} - \delta}{1-\gamma_i} - x_i\beta\right]/\sigma_i\right)
\end{aligned}
$$

Results: common scale

Table 4: Results, no covariates, homoscedasticity assumed, weighted by *wgt*.

	SB	DB	S	SA	SHA
WTP	5.302**	4.358**	4.598**	5.093**	5.148**
σ	4.453**	1.878**	1.879**	3.557**	3.677**
δ			-0.303**	-0.297**	-0.342**
γ					
howsure					-0.045**
SECONDpair					0.052+
constant				0.547**	0.858**
N	1417	1417	1417	1417	1417
log-likelihood	-1035.41	-2063.99	-2013.03	-1980.43	-1921.74
AIC	2074.83	4131.99	4032.05	3968.86	3855.47

$^{+}\ p < 0.10$, $^{*}\ p < 0.05$, $^{**}\ p < 0.01$

SB: Single-Bounded Model; DB: Basic Double-Bounded Model;

S: Double-Bounded Model with Shift; SA: Double-Bounded Model with Shift and Anchoring;

SHA: Double-Bounded Model with Shift and Heterogenous Anchoring.

Results: variable scale

Table 5: Results, no covariates, no homoscedasticity assumed, weighted by *wgt*.

	SBh	DBh	Sh	SAh	SHAh
WTP	5.212**	4.304**	4.533**	5.019**	5.147**
σ					
howsure	-0.312*	0.099**	0.103**	0.327**	-0.012
SECONDpair	-1.213	-0.296+	-0.296+	-0.746+	-1.402*
constant	7.033**	1.293**	1.264**	2.342**	4.227**
δ			-0.306**	-0.301**	-0.344**
γ					
howsure					-0.046**
SECONDpair					-0.053
constant				0.635**	0.897**
N	1417	1417	1417	1417	1417
log-likelihood	-1031.24	-2046.52	-1994.62	-1949.84	-1917.32
AIC	2070.48	4101.05	3999.25	3911.68	3850.64

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

h suffix: no homoscedasticity assumed SB: Single-Bounded Model; DB: Basic Double-Bounded Model; S: Double-Bounded Model with Shift; SA: Double-Bounded Model with Shift and Anchoring; SHA: Double-Bounded Model with Shift and Heterogenous Anchoring.

Estimates of WTP

Table 9: Comparison of median WTP estimates. Single-bounded, double-bounded, shift, anchoring, and shift plus heterogeneous anchoring models.

Model	Single-Bounded	Double-Bounded	Shift	Shift and Anchoring	Shift plus Heterogeneous Anchoring
No covariates:					
Homoscedastic	201(85, 463)	78 (67, 92)	99 (84, 118)	163 (96, 280)	172 (99, 308)
Heteroscedastic	183 (103, 330)	74 (67, 82)	93 (83, 105)	151 (93, 244)	172 (108, 273)
Covariates:					
Homoscedastic	159 (136, 187)	75 (72, 77)	94 (91, 98)	145 (126, 166)	149 (138, 162)
Heteroscedastic	151 (88, 266)	73 (71, 76)	93 (91, 95)	145 (124, 169)	151 (118, 195)

95% confidence intervals in brackets.

Table 8: Results for model considering a shift and heterogeneous anchoring and including covariates, no homoscedasticity assumed, weighted by *wgt*.

	Regressors	Scale heterogeneity and question effects	
WTP		σ	
logdiffM	0.552^{+}	howsure	-0.084
logdiffI	0.068*	SECONDpair	-0.941*
logincome	0.337^{+}	constant	3.974**
male	-0.643*	δ	
logage	-1.034^{+}	constant	-0.338**
childrenany	-0.532^{+}	γ	
Avalon	0.521^{+}	howsure	-0.051**
SUV	0.360	SECONDpair	-0.018
drives30towork	0.925**	constant	0.891**
KMyear	-0.013^{+}	N	1417
knowselse	1.551**	log-likelihood	-1787.43
hitmoose	0.494	AIC	3632.85
baseline	-0.077^{+}	$\chi 2$	37.86
baselineI	0.001		
Version D	1.211*		
Version F	1.064*		
publicgood	0.474^{+}		
privatefirst	-0.092		
SECONDpair	-0.401^{+}		
inpuage	-0.525		
inpuincome	-1.153**		
constant	5.901*		

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Some scope sensitivity but not close to proportional

Different people have different expected WTP

Conclusions: "take 1"

- {More mathematically skilled respondents lead to more efficient estimation of the value of risk reductions}
- Those who are more sure about their answers can be also more *extreme* in their responses beyond what we specified as the systematic component of the WTP conditional mean function, although this is not significant when the SB model is used or *howsure* is used to model heterogenous anchoring
- It is difficult to pinpoint the source of scale heterogeneity, most of all when other effects must be modelled too
- It might not make much of a difference in practice…

What now?

- What was this exercise all about?
- How should we sue the output?
- Basic use: pick the mean, aggregate to the population and compare that total benefit with the total cost = > CBA
- Some individual will win some will lose but in aggregate “society” wins

But

- The decision based on the HKC might not seem fair
- Should poorer individuals be asked to contribute to a risk reduction that might not be their priority?

- Is that fair?

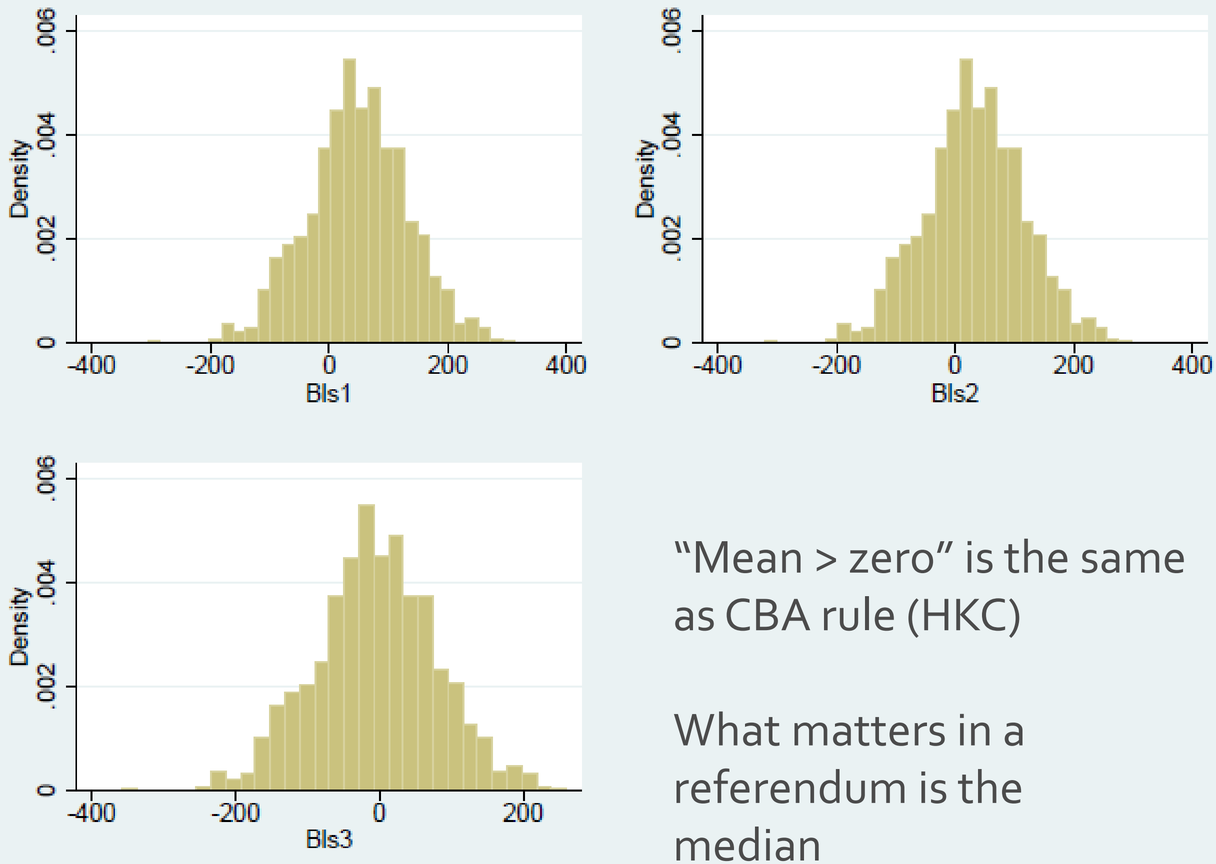
Rethinking "efficiency" as a rule

- The decision based on the HKC might not seem fair
- Indeed, do we have alternative mechanisms to aggregate individual preferences
- How about a referendum?
- One person one vote (no longer one dollar one vote)
- NB: we no longer allow individual to reveal the intensity of their preferences now…

Referendum => Net individual WTP matters

- Now we cannot just look at the mean WTP
- We want to know about the median too, since the median, is it also more than zero?
- And we want to decide how to allocate the cost of the policy among individuals..
- If they contribute differently and their WTP is different, we need to know about the distribution of net WTP

Rethinking "efficiency" as a rule



"Mean > zero" is the same as CBA rule (HKC)

What matters in a referendum is the median

Figure 2: Histograms of predicted WTP, net of lump-sum contributions, Projects 1, 2, and 3 $(\widehat{Bls_i})$.

More realistic: progressive fee

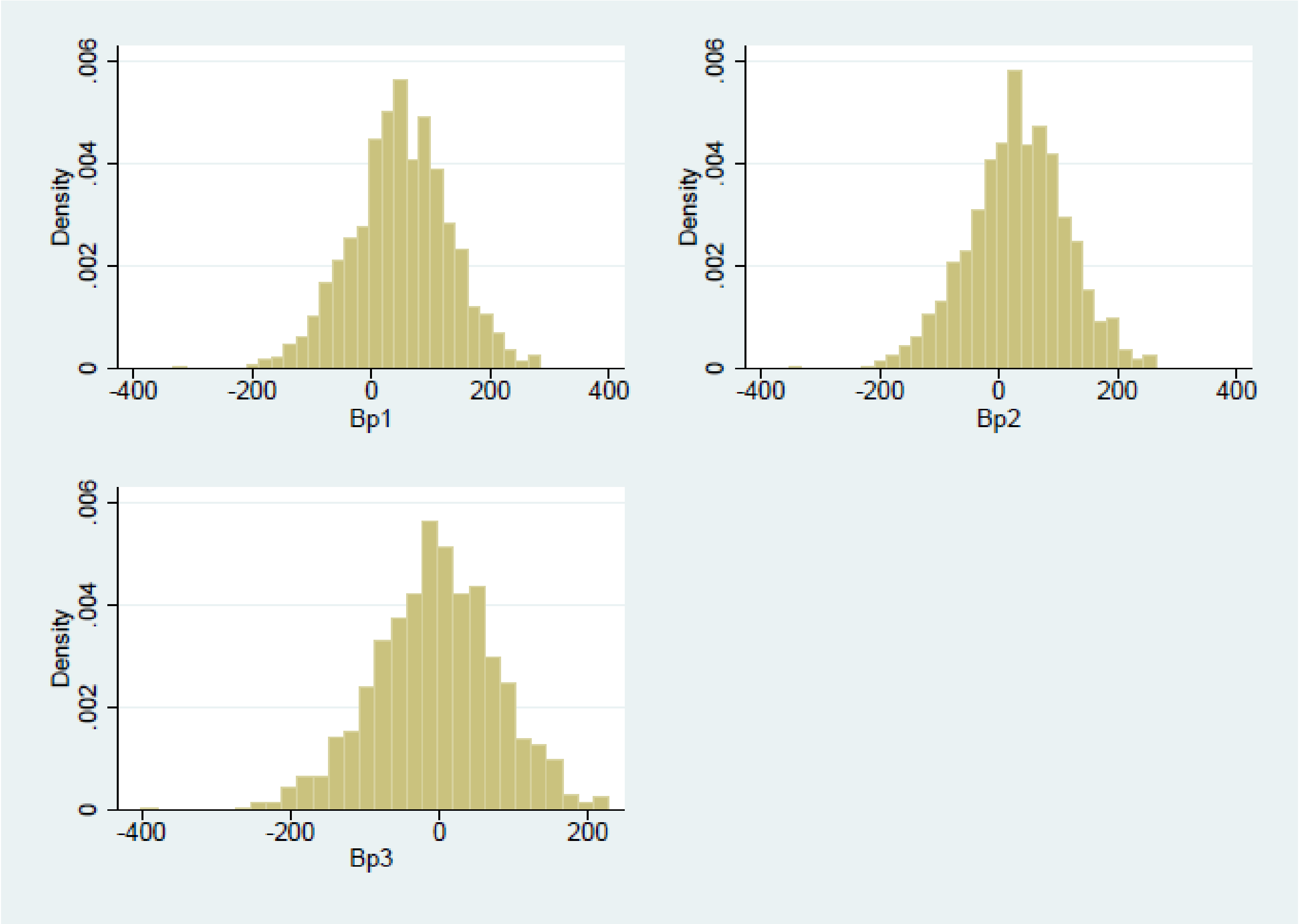


Figure 3: Histograms of predicted WTP, net of progressive contributions, Projects 1, 2, and 3 $(\widehat{Bp_i})$.

Fee based on estimated risk (*benefit principle* of taxation)

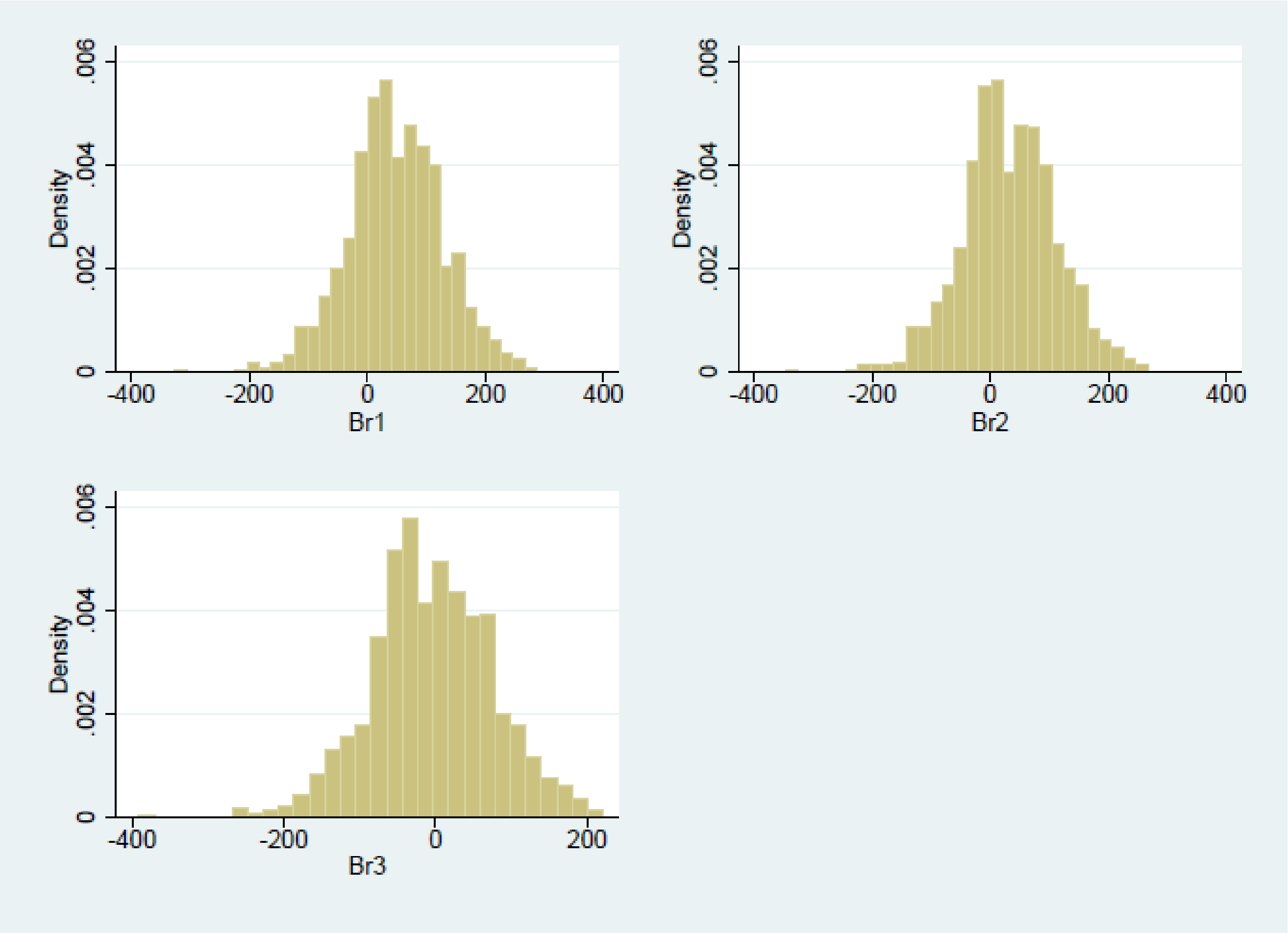


Figure 4: Histograms of predicted WTP, net of risk-based contributions, Projects 1, 2, and 3 ($\widehat{Br_i}$).

Fee based on perceived own risk (also *benefit principle* of taxation)

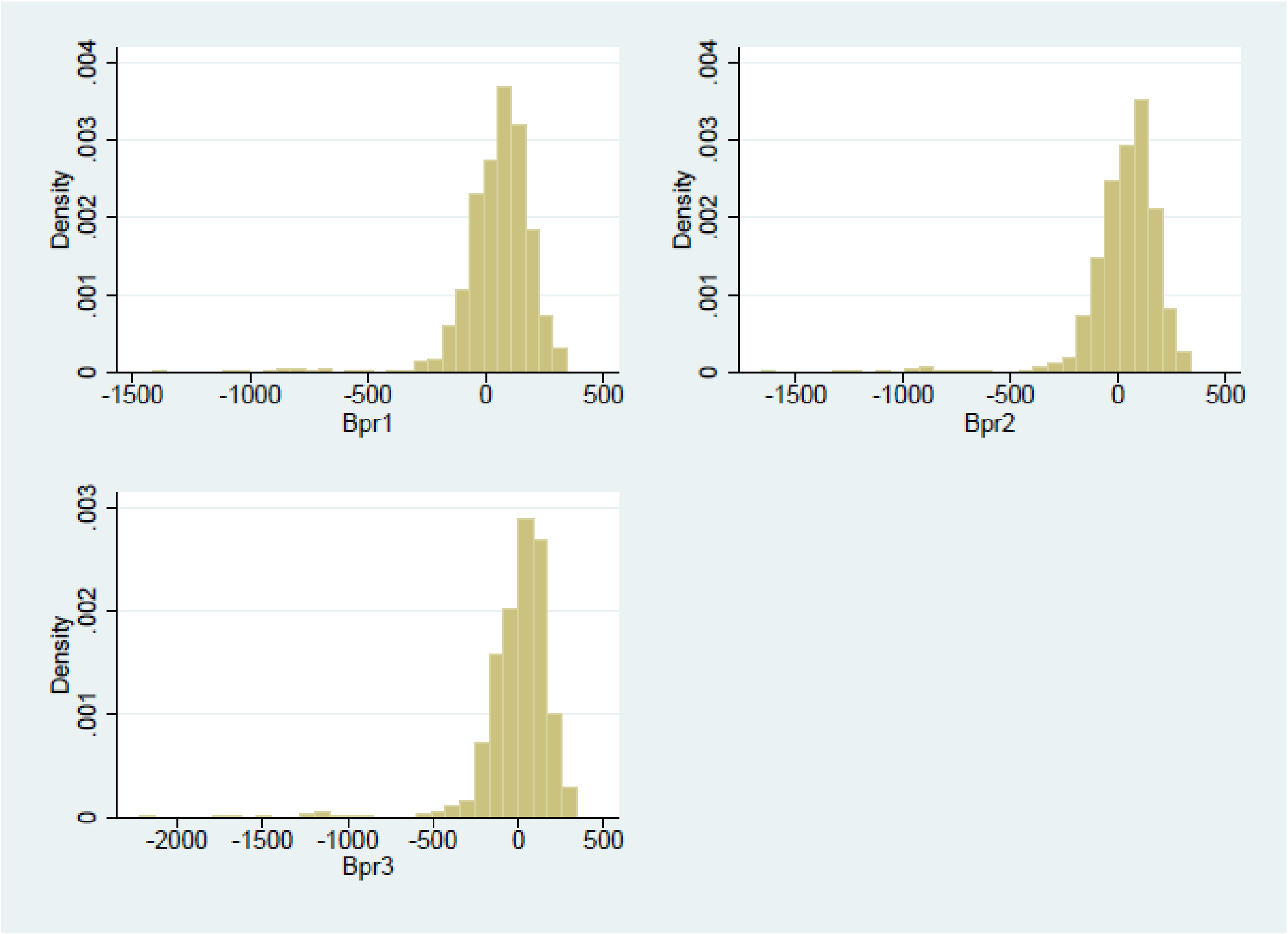


Figure 5: Histograms of predicted WTP, net of perceived risk-based contributions, Projects 1, 2, and 3 ($\widehat{Bpr_i}$).

Conclusions “take 2”

- If we use a referendum instead of CBA
- The choice of financing schemes has negligible effects on political desirability
- Why? Because relatively small costs of the risk reduction policies considered, most choices of financing scheme based on distributional considerations (fairness) do not affect the decision
- Net WTP remains distributed approximately normally, with the effect of netting out expected contributions from individual WTP not altering substantially neither the variance nor the symmetry of the gross WTP variable, which always had a median (and a mean) larger than zero
- Exception: if costs were shared according to the individuals’ own perceived risk

Conclusions "take 2"

- Exception: if costs were shared according to the individuals' own perceived risk

Table 6: Mean and quartiles of predicted gross WTP (*WTPpredicted*) and net of contributions (B) under each financing scheme

	mean	p25	p50	p75
WTPpredicted	148.32	96.23	146.68	203.37
Bls1	48.08	-4.01	46.45	103.14
Bls2	31.87	-20.23	30.23	86.92
Bls3	-4.80	-56.89	-6.44	50.25
Bp1	48.08	-1.59	49.25	102.11
Bp2	31.87	-18.63	32.92	85.42
Bp3	-4.80	-54.99	-3.43	49.50
Br1	48.08	-1.69	45.58	100.22
Br2	31.87	-17.62	28.42	85.18
Br3	-4.80	-53.94	-7.05	49.86
Bpr1	48.08	-15.90	67.75	138.23
Bpr2	31.87	-36.15	59.18	129.88
Bpr3	-4.80	-82.24	35.58	113.31
N	1102			

This referendum would pass Project 3 which is *inefficient*

Conclusions “take 2”

- CBA might be unfair
- But for many decisions about relatively small projects, accounting for distributional considerations might not even make a difference
- Most of all if contributions are paid through progressive taxes and benefits are correlated with income

Thanks

- Memorial University's **CARE** (Collaborative Applied Research in Economics) provided the funding for this research project

Variable	definition	Mean	S.D.	Min.	Max.
WTP Explanatory variables					
male	Indicator: respondent is male	0.486	0.5	0	1
income	Ordered categorical variable: [0-30,000][30,000-50,000][50,000-70,000]...[130,000-150,000][150,000-$+\infty$]; (CAD/year). Treated as approximately continuous variable by replacing categories with interval median values (and by 250,000 for uppermost open interval, before taking logs to construct *logincome*	1.193	0.672	0	2.079
logage	Log of respondent's age	52.202	13.749	19	85
childrenany	Indicator: members under 18 in the household	0.323	0.468	0	1
inpuage	Indicator: *age* was inputted	0.09	0.286	0	1
inpuincome	Indicator: income was inputted	0.188	0.391	0	1
Avalon	Indicator: respondent lives in the most urban and densely populated region of Newfoundland	0.534	0.499	0	1
SUV	Indicator: main vehicle driven by respondent is a SUV	0.411	0.492	0	1
drives30towork	Indicator: respondent commutes at least 30 Km for work	0.17	0.376	0	1
KMyear	Approximate number of Km driven per year self-estimated	20.098	21.38	0	300
hitmoose	Indicator: respondent suffered a MVC or a close call on a Newfoundlad highway	0.802	0.398	0	1

knowselse	Indicator: respondent personally knows of someone who suffered a MVC	0.735	0.441	0	1
firstbid	Initial bid in DBDC payment question	80.928	54.56	15	500
logdiffM	Log of the difference between the baseline death risk (*baseline*) and the actual risk after the adoption of the safety device (in Versions A, B, E, and F) or the policy (in Versions C, D, E, and F)	1.155	0.877	-0.693	3.624
logdiffI	Log of the difference between the baseline risk of injury (*baselineI*) and the actual risk after the adoption of the safety device (in Versions A, B, E, and F) or the policy (in Versions C, D, E, and F)	-3.003	6.674	-9.210	6.62
baseline	Baseline death risk rate (per 100,000), given by *RM* or *owndeathrisk*	6.872	5.555	1	50
baselineI	Baseline injury risk rate (per 100,000), given by *RI* or *owninjuryrisk*	175.964	135.204	1	1,000
publicgood	Indicator: the payment question refers to a scenario that involves a public policy to reduce the risk of MVCs	0.483	0.5	0	1
privatefirst	Indicator: private good scenario (instead of the public good one) was proposed within Versions E and F	0.233	0.423	0	1
Version D	Indicator: Version D of questionnaire used	0.121	0.326	0	1
Version F	Indicator: Version F of questionnaire used	0.193	0.395	0	1
comprehensive	Indicator: the scenario involves a reduction in the risk of both death risk and morbidity risk	0.485	0.5	0	1

howsure	Numerical certainty scale measuring response certainty to payment questions	7.536	2.64	1	10
SECONDpair	Indicator: the response analyzed to generate the observation was the second one from those respondents who received Version E or F	0.222	0.416	0	1
Other variables					
RM	The death risk rate suggested to respondent (per 100,000)	8.154	2.857	4	12
RI	Injury risk rate suggested to respondent (*RM* times 30)	244.615	85.697	120	360
owndeathrisk	Subjective perceived death risk rate (per 100,000)	5.828	8.266	1	99
owninjuryrisk	Subjective perceived injury risk rate (per 100,000)	100.791	158.852	0	2500
MULTI	Divisor of *baseline* and *baselineI* used to calculate size of risk reductions. Values: 2, 3 and 4	3.008	0.822	2	4