Appendix A for "Multi-level regression and post-stratification for discrete choice modelling and stated preference research"

Region-level (i.e. Level-2) variables in the MRP model

In the Saskatchewan River Delta (SRD) empirical example, several of the provinces only have a handful of respondents given the quota-sampling strategy employed. For example, only 4 respondents were from Prince Edward Island. To facilitate the pooling of preference information, one can include additional parameters that help explain preference differences among provinces. For example, a region random parameter which groups provinces of Canada into four regions[1] can be included or provincial-level variables such as the average right-wing political party vote share in the 2021 election (X_{rw}).[2] The purpose of these 'Level 2' variables is to help inform the imputation of WTP in step 2.

The revised specification for Equation (9) is now

$$\omega_i = \beta_0 + \alpha^{age-gender}_{a,g[i]} + \alpha^{province}_{p[i]} + \alpha^{income}_{m[i]} + \alpha^{education}_{e[i]}$$

$$\alpha^{age-gender}_{a,g} \sim N(0, \sigma^2_{age-gender}), \quad \text{for } a = 1,..,5,\ g = 1,2 \tag{1}$$

$$\alpha^{income}_{m} \sim N(0, \sigma^2_{income}), \quad \text{for } m = 1,...,7 \tag{2}$$

$$\alpha^{education}_{e} \sim N(0, \sigma^2_{education}), \quad \text{for } e = 1,...,5 \tag{3}$$

$$\alpha^{province}_{p} \sim N(\alpha^{region}_{r[p]} + \beta_1 X_{rw}, \sigma^2_{province}), \quad \text{for } p = 1,...11 \tag{4}$$

$$\alpha^{region}_{r} \sim N(0, \sigma^2_{region}), \quad \text{for } r = 1,...4 \tag{5}$$

With only 11 provinces, there is little empirical benefit gained from inclduing these Level-2 variables in the current SRD setting. However, for contexts were there are many more geographic regions to predict, such as the 50 American states, the appeal of using these Level-2 variables is higher.

[1] The four regions include British Columbia and the 3 northern territories, the three prairie provinces (Alberta, Saskatchewan, and Manitoba), Ontario and Quebec, and Atlantic Canada (New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador).

[2] The right wing vote share aggregates the vote share for the two main right wing parties in that election: Conservative Party of Canada and the People's Party of Canada.

Additional Tables and Figures

Table A1: WTP-space logit model estimates for a provincial wetland restoration program across the 3 Prairie provinces

	Alberta	Saskatchewan	Manitoba	All 3 Priarie Provinces
Scale (λ)	0.150 (0.025)	0.241 (0.044)	0.156 (0.025)	0.165 (0.016)
Program constant	1.118 (0.171)	1.159 (0.169)	1.630 (0.115)	1.383 (0.078)
nObs	870	318	811	1999

The program constant can be interpreted as the WTP for a provincial wetland restoration program in hundreds of dollars because of the cost rescaling for estimation. Parameter diagnostic metrics for R-hat and effective sample size are provided in Table A5.

Table A2: WTP-space MRP model estimates for a provincial wetland restoration program across the 3 Prairie provinces

	Alberta	Saskatchewan	Manitoba	All 3 Priarie Provinces
Scale (λ)	0.146 (0.026)	0.231 (0.048)	0.157 (0.026)	0.168 (0.017)
Program constant	0.720 (0.455)	0.774 (0.490)	1.421 (0.361)	1.077 (0.412)
SD age-gender	0.328 (0.291)	0.290 (0.273)	0.337 (0.249)	0.172 (0.135)
SD education	0.392 (0.352)	0.356 (0.347)	0.403 (0.324)	0.329 (0.226)
SD income	0.604 (0.444)	0.676 (0.456)	0.235 (0.169)	0.390 (0.187)
SD province				0.499 (0.406)
nObs	870	318	811	1999

The program constant can be interpreted as the WTP for a provincial wetland restoration program in hundreds of dollars because of the cost rescaling for estimation. Parameter diagnostic metrics for R-hat and effective sample size are provided in Table A6.

Table A3: WTP-space MRP model estimates for a provincial wetland restoration program using the validity sample

	Alberta	Saskatchewan	Manitoba	All 3 Priarie Provinces
Scale (λ)	0.112 (0.030)	0.230 (0.063)	0.155 (0.036)	0.150 (0.022)
Program constant	-0.410 (0.769)	0.185 (0.721)	1.175 (0.443)	0.569 (0.602)
SD age-gender	0.630 (0.790)	0.502 (0.534)	0.634 (0.458)	0.321 (0.286)
SD education	0.837 (1.124)	0.580 (0.697)	0.285 (0.291)	0.249 (0.238)
SD income	0.847 (0.782)	0.706 (0.704)	0.248 (0.238)	0.339 (0.255)
SD province				0.889 (0.669)
nObs	526	192	459	1177

The program constant can be interpreted as the WTP for a provincial wetland restoration program in hundreds of dollars because of the cost rescaling for estimation. Parameter diagnostic metrics for R-hat and effective sample size are provided in Table A7.

Table A4: Diagnostics (Rhat, ESS) for SRD restoration program WTP-space logit models

Model	Term	Rhat	ESS(bulk)	ESS(tail)
MNL	Mean Sturgeon	1.00	3867	3295
MNL	Mean Habitat	1.00	3215	2701
MNL	Mean Waterfowl	1.00	3397	3161
MNL	Mean Muskrat	1.00	3824	2918
MNL	Scale (λ)	1.00	3022	2714
MNL	Program constant	1.00	2488	2788
RPL	Mean Sturgeon	1.00	4699	3425
RPL	Mean Habitat	1.00	5793	3621
RPL	Mean Waterfowl	1.00	7336	3452
RPL	Mean Muskrat	1.00	5788	3192
RPL	Scale (λ)	1.00	2337	2786
RPL	Program constant	1.00	1190	2040
RPL	SD Program: individual	1.00	1578	2420
RPL	SD Habitat: individual	1.00	1154	1941
RPL	SD Sturgeon: individual	1.00	1284	1572
RPL	SD Muskrat: individual	1.00	790	1210
RPL	SD Waterfowl: individual	1.01	391	1062
MRP	Mean Sturgeon	1.00	1518	1955
MRP	Mean Habitat	1.01	1284	1404
MRP	Mean Waterfowl	1.00	1504	1689
MRP	Mean Muskrat	1.00	1518	1918
MRP	Scale (λ)	1.00	5821	2891
MRP	Program constant	1.00	5422	3108
MRP	SD Habitat: age-gender	1.00	1324	1588
MRP	SD Habitat: education	1.00	1352	1778
MRP	SD Habitat: income	1.00	1303	1439
MRP	SD Habitat: province	1.00	1229	1536
MRP	SD Sturgeon: age-gender	1.00	1362	1967
MRP	SD Sturgeon: education	1.00	1280	1902
MRP	SD Sturgeon: income	1.00	1637	1667
MRP	SD Sturgeon: province	1.00	1103	1641
MRP	SD Muskrat: age-gender	1.00	1431	1243
MRP	SD Muskrat: education	1.00	1238	2358
MRP	SD Muskrat: income	1.00	1222	1454
MRP	SD Muskrat: province	1.00	1362	1127
MRP	SD Waterfowl: age-gender	1.00	1448	1575
MRP	SD Waterfowl: education	1.00	1391	2162
MRP	SD Waterfowl: income	1.00	2160	1579
MRP	SD Waterfowl: province	1.00	1613	1732

Table A5: Diagnostics (Rhat, ESS) for WTP-space wetland logit models

Model	Term	Rhat	ESS(bulk)	ESS(tail)
Alberta	Program constant	1	2237	1871
Alberta	Scale (λ)	1	2491	2228
Saskatchewan	Program constant	1	2059	1458
Saskatchewan	Scale (λ)	1	2378	1708
Manitoba	Program constant	1	1785	1557
Manitoba	Scale (λ)	1	1666	1480
All 3 Prairie Provinces	Program constant	1	2139	1771
All 3 Prairie Provinces	Scale (λ)	1	2169	2620

Note:
Rhat close to 1.00 indicates convergence; ESS values represent effective sample sizes for bulk and tail distributions.

Table A6: Diagnostics (Rhat, ESS) for WTP-space wetland MRP models

Model	Term	Rhat	ESS(bulk)	ESS(tail)
Alberta	Program constant	1.00	2528	2337
Alberta	SD age-gender	1.00	1487	1452
Alberta	SD education	1.00	1863	2058
Alberta	SD income	1.00	1372	1478
Alberta	Scale (λ)	1.00	4004	2250
Saskatchewan	Program constant	1.00	1369	946
Saskatchewan	SD age-gender	1.00	1967	1785
Saskatchewan	SD education	1.00	1715	1551
Saskatchewan	SD income	1.00	1221	1318
Saskatchewan	Scale (λ)	1.00	3356	2189
Manitoba	Program constant	1.00	826	556
Manitoba	SD age-gender	1.00	1286	1427
Manitoba	SD education	1.01	687	597
Manitoba	SD income	1.00	1499	2113
Manitoba	Scale (λ)	1.00	3271	2198
All 3 Prairie Provinces	Program constant	1.00	1371	1390
All 3 Prairie Provinces	SD age-gender	1.00	1316	1289
All 3 Prairie Provinces	SD education	1.00	1335	1217
All 3 Prairie Provinces	SD income	1.00	1318	2003
All 3 Prairie Provinces	SD province	1.00	1304	1821
All 3 Prairie Provinces	Scale (λ)	1.00	3896	2619

Note:
Rhat close to 1.00 indicates convergence; ESS values represent effective sample sizes for bulk and tail distributions.

Table A7: Diagnostics (Rhat, ESS) for WTP-space wetland MRP models using the validity sample

Model	Term	Rhat	ESS(bulk)	ESS(tail)
Alberta	Program constant	1	3057	2732
Alberta	SD age-gender	1	2423	1921
Alberta	SD education	1	2189	2161
Alberta	SD income	1	1830	1763
Alberta	Scale (λ)	1	2777	2155
Saskatchewan	Program constant	1	2658	2080
Saskatchewan	SD age-gender	1	2473	1879
Saskatchewan	SD education	1	2012	1838
Saskatchewan	SD income	1	1574	1832
Saskatchewan	Scale (λ)	1	3029	1897
Manitoba	Program constant	1	1644	1326
Manitoba	SD age-gender	1	1409	1798
Manitoba	SD education	1	1795	1971
Manitoba	SD income	1	1714	1985
Manitoba	Scale (λ)	1	3500	1670
All 3 Prairie Provinces	Program constant	1	1993	1458
All 3 Prairie Provinces	SD age-gender	1	1371	1804
All 3 Prairie Provinces	SD education	1	1769	1915
All 3 Prairie Provinces	SD income	1	1630	1704
All 3 Prairie Provinces	SD province	1	1734	1545
All 3 Prairie Provinces	Scale (λ)	1	4148	2470

Note:
Rhat close to 1.00 indicates convergence; ESS values represent effective sample sizes for bulk and tail distributions.

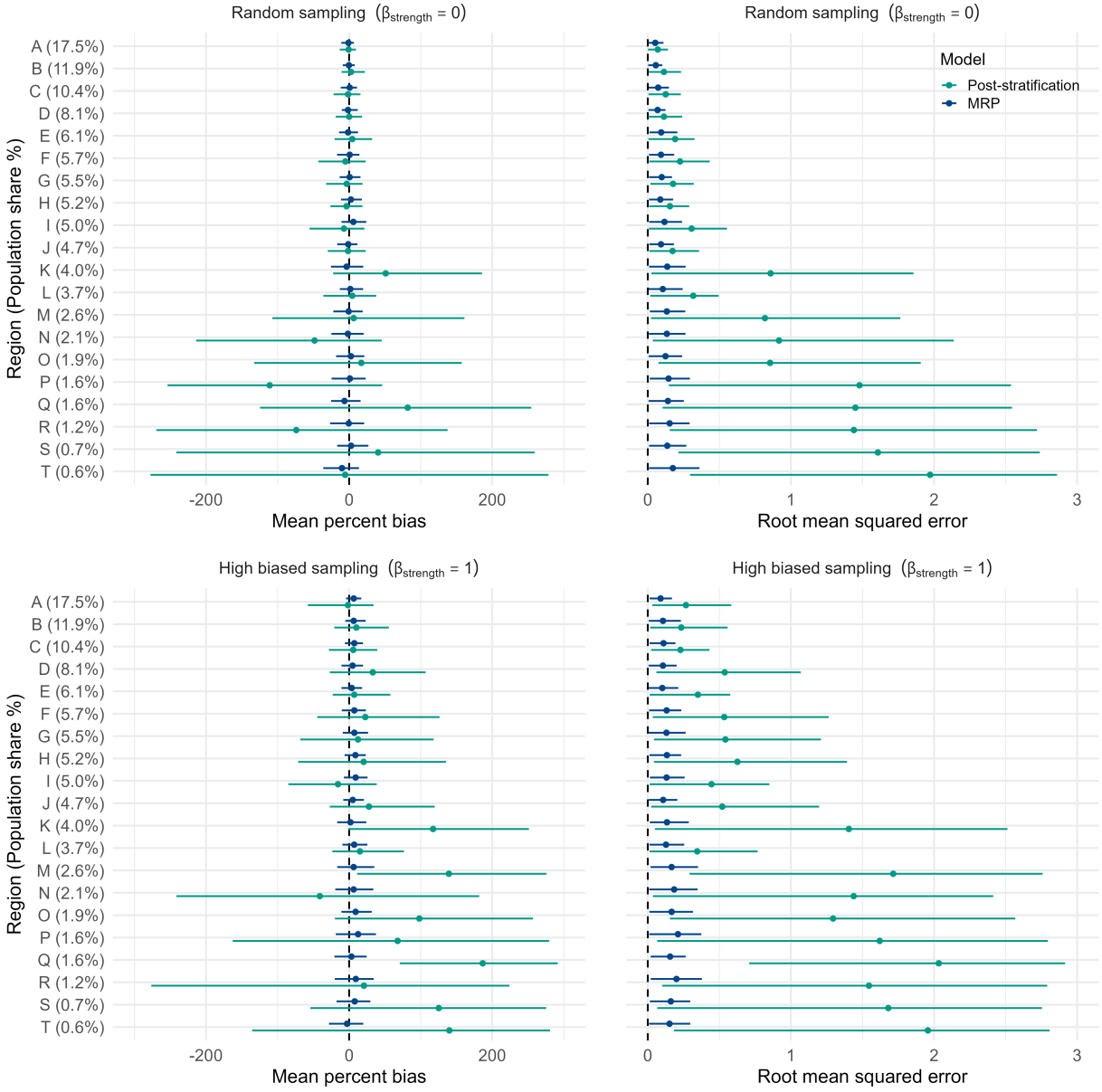

Figure A1: Comparison of MRP and post-stratification for regional WTP estimation with 3000 survey sample

If Alberta holds a provincial referendum to determine whether to put into place the Wetland Restoration Plan and you are asked to vote for or against the program, what would you choose?

Please read the following two statements and choose the one that indicates how you would vote.

___**I vote Yes.** I am willing to pay $125 more in annual provincial income taxes for my household for 10 years starting in January 2022 to pay for the Wetland Restoration Plan that increases the amount of wetlands by 10% in the Prairie Pothole region of Alberta.

___**I vote No.** I am not willing to pay $125 more in annual provincial income taxes for my household for 10 years starting in January 2022 to pay for the Wetland Restoration Plan that increases the amount of wetlands by 10% in the Prairie Pothole region of Alberta.

Figure A2: Example of single binary choice question for wetland survey

Alternatives A and B are potential Saskatchewan River Delta futures. The Status Quo alternative means no new conservation occurs. Given the choice between these three alternatives, how would you vote?

	Results in 20 years		
	Status Quo	Alternative A	Alternative B
Lake Sturgeon	**30%** 3,000 of 10,000 fish conservation target	**15%** 1,500 of 10,000 fish conservation target	**100%** 10,000 of 10,000 fish conservation target
Waterfowl population	**25%** 200,000 of 800,000 breeding ducks possible	**50%** 400,000 of 800,000 breeding ducks possible	**75%** 600,000 of 800,000 breeding ducks possible
Muskrat abundance	**5%** 1 muskrat found per hectare out of 20 possible	**30%** 6 muskrats found per hectare out of 20 possible	**60%** 12 muskrats found per hectare out of 20 possible
Habitat in healthy ecological condition	**45%** 405,000 of 900,000 hectares	**60%** 540,000 of 900,000 hectares	**75%** 675,000 of 900,000 hectares
Annual cost to your household for 20 years	**$0** Increase in annual taxes for 20 years	**$15** Increase in annual taxes for 20 years	**$325** Increase in annual taxes for 20 years
I would vote for…	☐ Status Quo	☐ Alternative A	☐ Alternative B

Figure A3: Example of a choiceset for the Saskatchewan River Delta (SRD) study

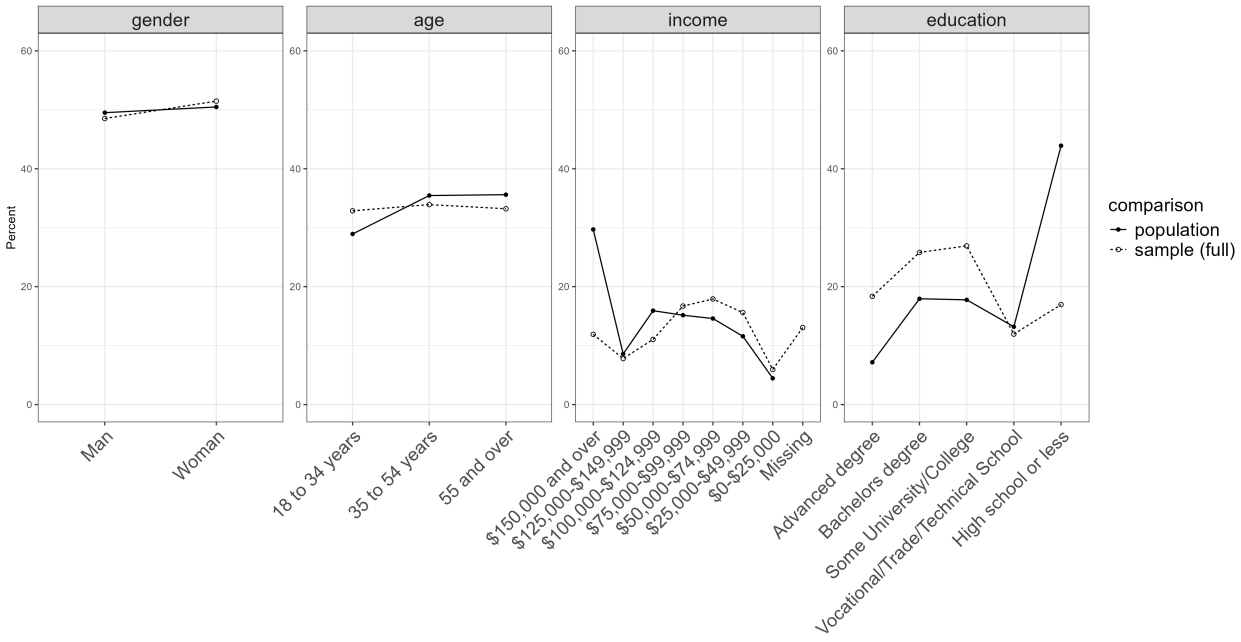

Figure A4: Comparison of wetland survey sample and target population across all three Priarie provinces

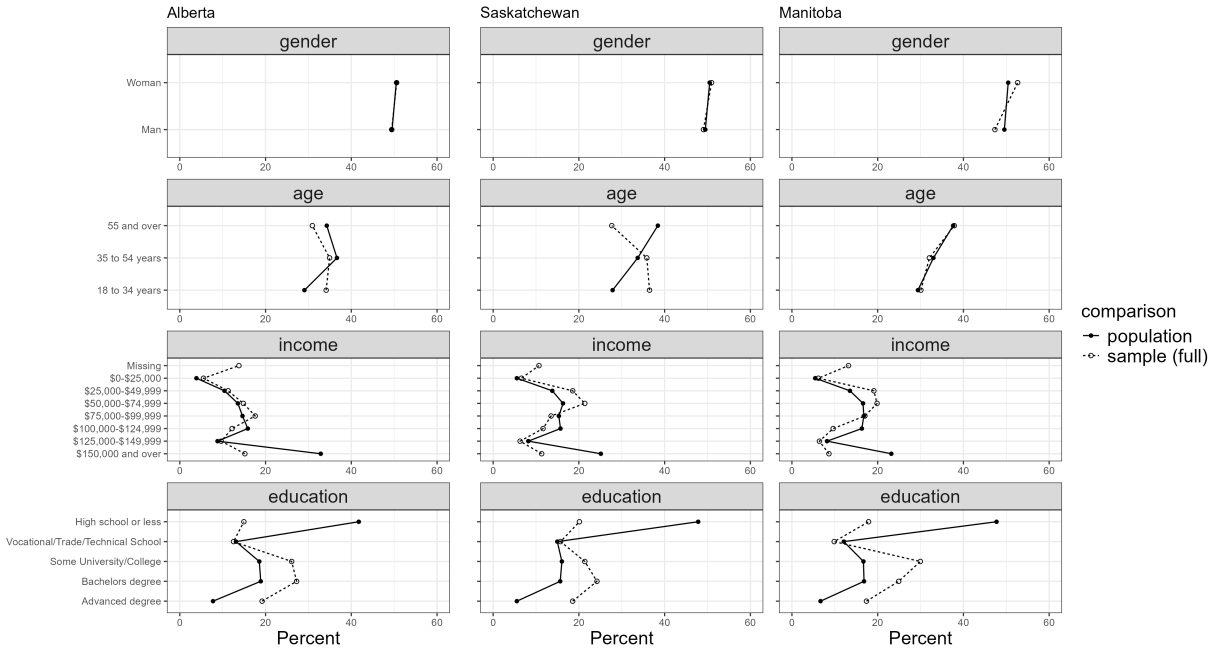

Figure A5: Comparison of wetland survey sample and target population for each province

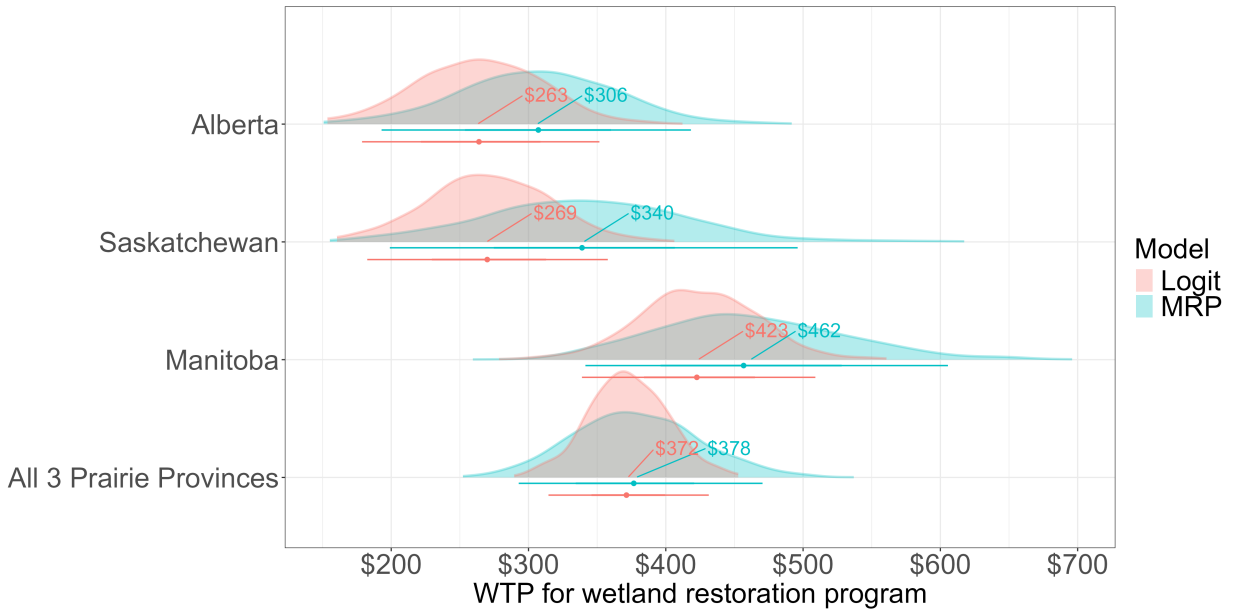

Figure A6: WTP for wetland restoration using alternative Logit and MRP specifications without exponentiation

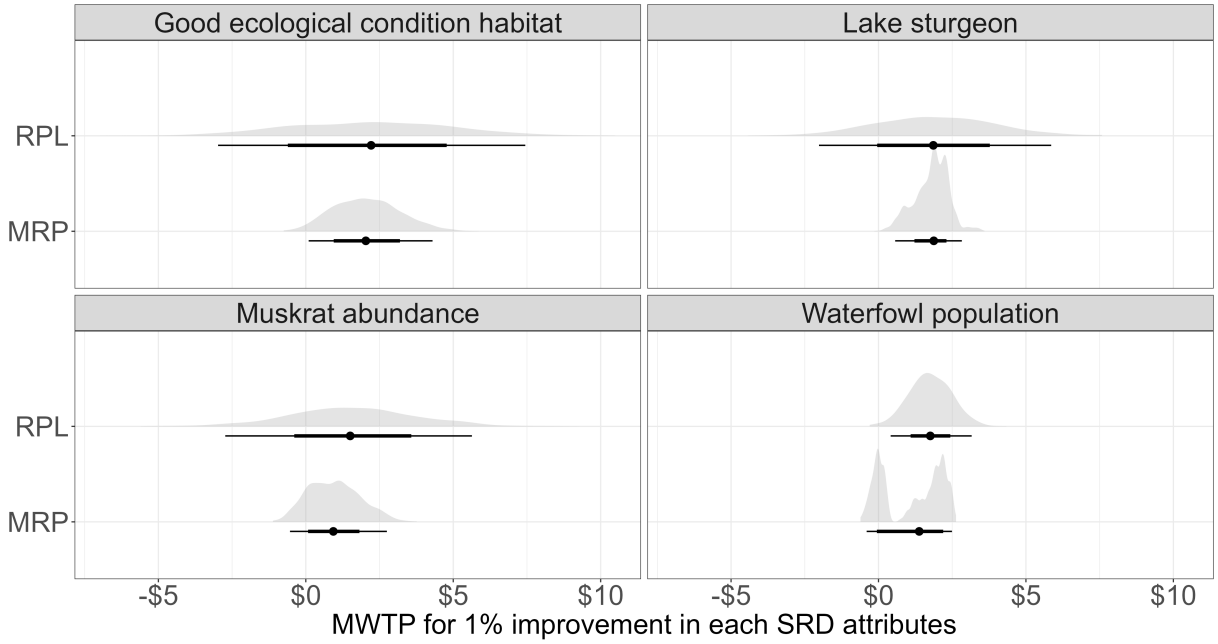

Figure A7: Distribution of MWTP for each SRD attribute using the MRP and RPL approach

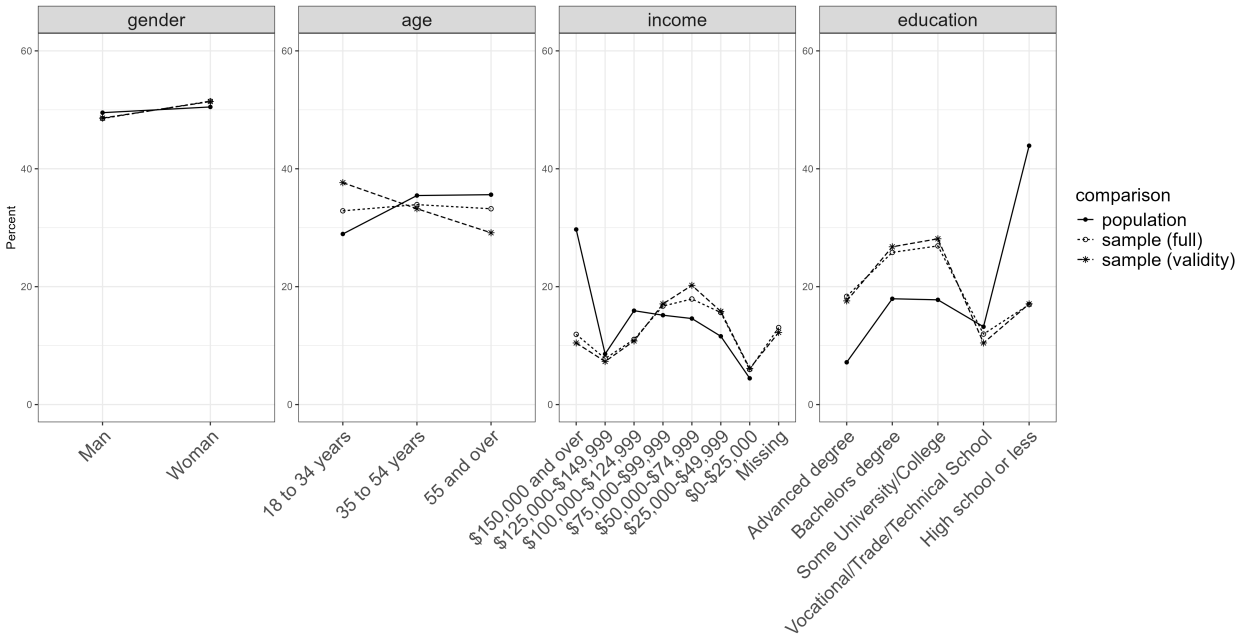

Figure A8: Comparison of wetland study sample, validity sample, and population across all three Priarie provinces

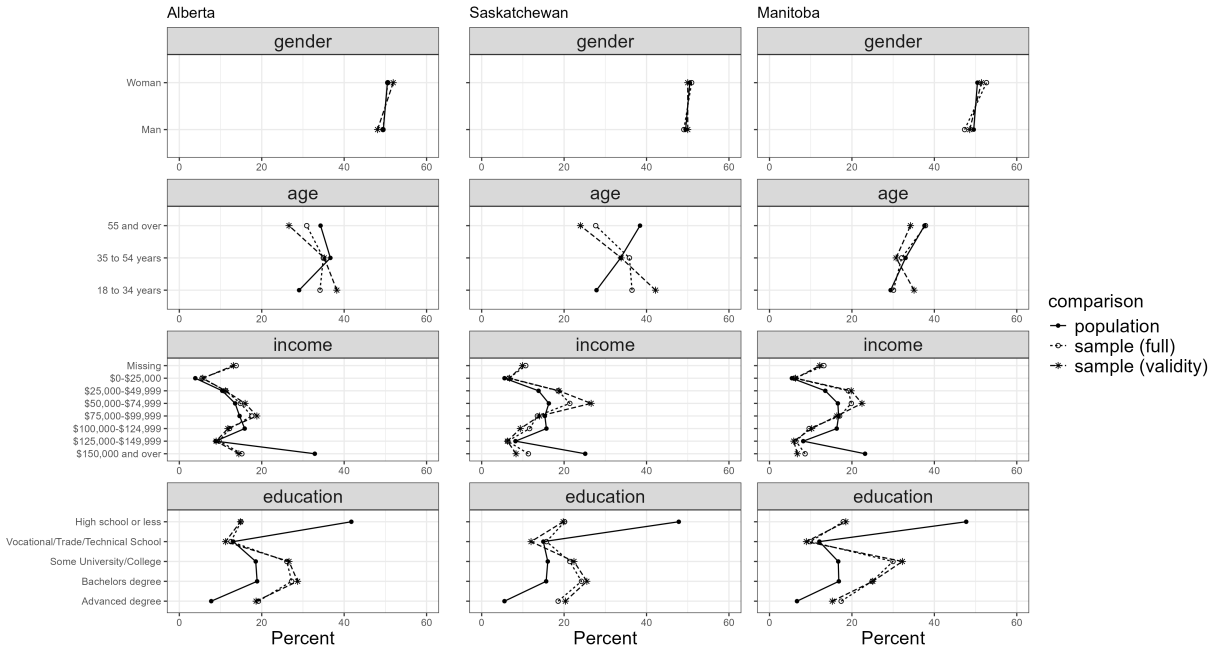

Figure A9: Comparison of wetland study sample, validity sample, and population for each province