**Prairie Wetland Loss is Associated with Substantial Economic Costs to Society**

**Abstract**

Estimates of the monetary value of wetlands in Canada can help support the development of wetland conservation policies. However, there are few wetland valuation studies that can represent Canadian wetland systems. In this study, we develop meta-regression value functions that uses US only and US-Canada wetland valuation meta-data and compare their effectiveness at predicting wetland values, in terms of prediction errors. The final meta data for this study includes 43 observations from 8 Canadian (17 observations) and 17 US (25 observations) studies. Our results shows that the benefit transfer error from using US-Canada data (in a meta-regression) to predict Canadian wetland values is about 263% lower than using US only data. We also identified important variables that explained the willingness to pay (WTP) to conserve wetlands in the US-Canada including log wetland acreage, log wetland acreage change, wetland study at the sub-province or sub-state level (local), provisioning and regulating ecosystem services. We applied the US-Canada meta-regression model to estimate the economic loss of wetland area, Saskatchewan (112,574 acres), Alberta (28,252 acres) and Manitoba (11,734 acres) between 2001 and 2011 to be …, …., and …., respectively.

1. **Introduction**

The world has lost more than 50 percent of its original wetland area at a greater rate than other ecosystem loss in the world (Millennium Ecosystem Assessment, 2005; Mitsch and Gosselink, 2007). Canada has approximately 1.5 million km2 of wetlands which is about 28% of total wetlands in the world (Reimer, 2009). However, it has been estimated that up 20 million acres of wetlands have been lost in Canada since pre-European settlement (Environment Canada, 2009), mainly through agricultural development (Badiou et al. 2011; Watmough and Schmoll, 2007). Other drivers of wetland loss in Canada include urban development, transportation, resource extraction and mining, and recreational development. About 40 to 71% of historical wetland area has been lost in the Canadian Prairies (Kraus, 2019) at an annual rate of about 0.53% (Watmough and Schmoll, 2007).

Wetlands provide important ecosystem services to society but understanding the economic benefits of these services remain a challenge. Some of the ecosystem services of wetlands are carbon sequestration, recreation, tourism, human and livestock foods, habitat to support diverse biotic communities (Davies et al. 2008; Badiou et al. 2011; Gleason et al. 2011; De Groot et al. 2012), regulating and recharging aquifers (Dixon and Wood 2003) and removal of excess nutrients and pesticides from agricultural lands (Vymazal 2017). The economic value of wetland ecosystem services has been estimated in several regions of the world, including Nakivubo wetlands in Uganda (Schuijt, 2002), Muthurajawela wetland in Sri Lanka (Emerson and Kekulandala, 2003); flood plains of the Elbe River in Germany (Meyerhoff and Dehnhardt, 2004); and Upper Paraná River floodplain in Brazil (Carvalho, 2007). In Canada, the economic value of wetland ecosystem services has been estimated, but the empirical evidence is limited (Lloyd-Smith, et al., 2020).

Need for policy-ready valuation tools as wetlands continue to be degraded. Conducting new research addressing primary valuation is often infeasible due to time, costs, and resource constraints, making the use of benefit transfer techniques widespread in policy settings. Currently, mean value transfer has been the most popular approach to the valuation of wetlands in Canada, where $/acre is derived from prior research to value wetlands in new settings (Belcher et al. 2001; Dupras and Alam, 2015; Dupras et al. 2015). Although mean value unit value transfer is relatively inexpensive and faster to implement, it has a mean transfer error of about 45% (Rosenberger and Loomis, 2017) which is higher than the transfer error of the meta-analysis benefit function at 36% (Rosenberger and Loomis, 2017). Wetland benefit estimates could be used in benefit-cost calculations to justify the need to conserve wetlands.

The purpose of this study is to develop and apply a Canadian wetland economic valuation model using recent advances in meta-analysis modeling of environmental valuation data. To do so, we extend the modeling framework of Moeltner et al. (2019) to include Canadian studies and estimate a Canada-US wetland valuation model. We focus on stated preference valuation studies as the primary method for estimating non-use values, including wetland ecosystem services. A total of 8 Canadian valuation studies (17 observations) and 17 US valuation studies (25 observations) produced 43 meta-data observations. We estimate several model specifications including log-linear and log-log models.

We find evidence that WTP to conserve wetlands increase with wetland area change, which is consistent with sensitivity to scope assumption, for the US-Canada data meta-regression but not for the US data meta-regression. For instance, we estimate that a 1% increase in wetland acreage change would cause about 0.46% increase in the willingness to pay to conserve the wetland acreage change. However, the two models fail in the adding up test, which states that the WTP to achieve a target wetland acreage should be equal to or less than the sum of incremental WTP estimates from achieving the same wetland acreage target but in sequential steps (Moeltner, 2019); however, adding up test is hardly validated in applied valuation work (Kling and Phaneuf, 2018). Also, we identify the log wetland acreage, log wetland acreage change, wetland study at the sub-province or sub-state level (local), provisioning and regulating ecosystem services as important variables that explained the willingness to pay (WTP) to conserve wetlands in the US-Canada data meta-regression. Moreover, we estimate that the mean meta-regression root mean squared error from using the US-Canada meta-regression model to predict Canadian wetland values is 263% lower than the mean error from the US meta-regression model. Also, the mean US-Canada meta-regression root mean square error is 80% less that the mean value root mean squared error.

We apply our model to estimate the economic value of wetland area loss between 2001 and 2011 in Canadian Prairie Habitat Joint Venture (PHJV) landscapes (Alberta, Saskatchewan, and Manitoba); the specific wetland area loss are 112,574 acres, 28,252 acres, and 11,734 acres for Saskatchewan, Alberta, and Manitoba, respectively (Prairie Habitat Joint Venture, 2014). The (PHJV) landscapes in the southern portion of the three provinces falls within the Prairie Pothole Region, and shares similar wetland and landscape characteristics with it. The PHJV was established through the North American Waterfowl Management Plan (NAWMP) in 1986 to protect wetlands in the Canadian Prairies which is the most important region for waterfowl breeding in North America (Prairie Habitat Joint Venture, 2014). The landscape contains approximately 11.3 million acres of wetlands, excluding lakes, river systems and the Alberta Peace lowlands (Watmough and Schmoll, 2007). Between 1985 and 2001 about 0.31% of the total wetland area in the PHJV region was lost each year, which is lower than the annual wetland loss (0.53%) in the greater Canadian Prairies region (Watmough and Schmoll, 2007). Wetland However, since 2007, about 1.58 million acres of wetlands and uplands have been restored or retained in the PHJV landscapes (Prairie Habitat Joint Venture, 2014). We find that the WTP to restore wetland acreage loss for a household in the Saskatchewan Prairie Habitat Joint Venture between 2001 and 2011 to be $14.50/household/year. Over the same period, the total economic loss for households in the 3 Canadian Prairie provinces resulting from the total wetland acreage losses in the PHJV landscapes are Alberta ($10,012,048 /year), Saskatchewan ($6,806,404 /year) and Manitoba ($2,002,414 /year); the total number of households in Saskatchewan, Alberta and Manitoba are 432,625, 1,527,675 and 489,050 respectively.

We contribute to the international meta-analysis literature by using valuation estimates from two countries. Our paper supports the observation in Johnson and Thomasin (2010) that, relying only on US wetland valuation studies to infer wetland values in Canada is not a best practice. Therefore, the paper agrees with the suggestion of Johnson and Thomasin (2010) for policymakers to adjust benefit transfer values, especially from US original studies to Canadian policy contexts to reduce transfer errors. Again, our paper will improve on the application of benefit transfer of wetland values in Canada, by providing the key factors or variables practitioners could use to control for differences between policy and original study sites.

This paper is structured into 6 sections. Section 2 compares the few wetland valuations studies that have been conducted in Canada. The data that will be used to estimate our model, and its descriptive statistics, as well as the background information on the meta-regression policy application setting (PHJV landscape in the Canadian Prairies) are discussed in section 3. The methodology of the study, including the meta-analysis econometric model, is described in section 4. Also, the procedure for estimating the meta-regression and mean value transfer errors, as well as the steps in estimating the economic loss associated with wetland acreage loss in the PHJV Canadian Prairies landscape are provided in section 4. Next, the results of our estimated model, the in-sample meta-function transfer errors, and the policy application are reported in chapter 5. The discussion of the results of the study and the conclusion, including the limitations of the study, and suggestions for future research are provided in section 6.

1. **Stated Preference Wetland Valuation Studies in Canada**

In many cases, environmental goods and services, such as wetland ecosystem services, have non-use values that are not observed in markets. This attribute makes the valuation of environmental amenities using traditional revealed preference or other market-based valuation methods impossible. Stated preference (SP) provides the only known method to estimate non-use values, including wetland ecosystem services, that are not observed in market conditions (Johnson et al. 2017). Moreover, they provide a means to estimate comparable and welfare consistent values from quantity and/or quality changes associated with environmental goods, such as changes in wetland area (Vedogbeton and Johnson, 2020). Therefore, we focused on studies that used stated preference to estimate the value of wetlands.

We searched the literature for Canadian wetland valuation studies from several sources including i) existing wetland meta-analyses, ii) the Environmental Valuation Reference Inventory (EVRI)[[1]](#footnote-1), iii) key word searches of environmental and resource economics journals as well as online databases such as EconLit and Google Scholar, iv) as well as a recent comprehensive review of environmental valuation studies in Canada (Lloyd-Smith, 2020).

We identified 9 wetland valuation studies in Canada that used stated preference methods to estimate people’s willingness to pay to retain or restore wetlands (Tkac, 2002; Ayokunle, 2003; Pattison et al. 2011; Lantz et al. 2013; Trenholm et al. 2013, Dias and Belcher, 2015; Vossler et al. 2020; Pattison et al. 2011; Rudd et al 2016; He et al. 2017). We retained studies on freshwater wetlands, and those that had information on baseline wetland acreage, the extent of wetland area changes and methodological attributes. We could not include Dias and Belcher (2015) in this study because it did not include enough information on baseline wetland acreage and extent of wetland change.

Eight studies on freshwater wetlands were used for this study. Some of these Canadian studies estimated multiple willingness to pay estimates for different wetland conservation scenarios. For example, Pattison et al (2011) considered four different wetland restoration scenarios at various percentages (80%, 83%, 89%, 100%) of 1968 wetland acreage and one wetland retention scenario. In total, we obtained 18 value observations for the Canadian meta-analysis dataset.

The contingent valuation method was used by all the studies to value wetlands, except Rudd et al. (2016) who used a choice experiment. Also, He et al (2017) compared the accuracy and effectiveness of contingent valuation and choice experiment in valuing wetlands. All the studies were published in peer-reviewed journals except Tkac (2002) and Ayokunde (2003). Moreover, the studies were different with regards to the sample sizes, location of the study, and data collection year (Table 1). Table A1 in appendix shows more information on the specific survey text used to describe the ecosystem services to respondents.

**Table 1. Comparison of Stated Preference Wetland Valuation Studies in Canada**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Prov** | **Data Collection Year** | **Sample Size** | **Restoration/Retention** | **Valuation Format** | **Ecosystem Service** | **Ch. Acres** | **WTP** |
| Tkac (2002) | ON | 2001 | 339 | Retention | CV (One Time) | Reg & Prov | 4,200 | 106 |
| Ayokunle (2003) | SK | 2003 | 196 | Retention | CV (An Cont.) | Cul | 555,975 | 65 |
| Pattisson et al. (2011) | MB | 2008 | 1980 | Retention and Restoration | CV (An Cont.) | Reg & Prov | 94,918 | 337 |
| Pattisson et al. (2011) | MB | 2008 | 1980 | Restoration | CV (An Cont.) | Reg & Prov | 135,598 | 345 |
| Pattisson et al. (2011) | MB | 2008 | 1980 | Restoration | CV (An Cont.) | Reg & Prov | 176,277 | 352 |
| Pattisson et al. (2011) | MB | 2008 | 1980 | Restoration | CV (An Cont.) | Reg & Prov | 257,636 | 367 |
| Pattisson et al. (2011) | MB | 2008 | 1980 | Restoration | CV (An Cont.) | Reg & Prov | 406,793 | 398 |
| Lantz et al. (2013) | ON | 2009 | 1407 | Retention | CV (An Cont.) | Reg & Prov | 3,000 | 498 |
| Lantz et al. (2013) | ON | 2009 | 1407 | Retention | CV (An Cont.) | Reg & Prov | 4,000 | 492 |
| Trenholm et al. (2013) | NB | 2007 | 299 | Retention | CV (An Cont.) | Reg, Cul & Prov | 5,884 | 36.9 |
| Trenholm et al. (2013) | NB | 2007 | 299 | Retention | CV (An Cont.) | Reg, Cul & Prov | 11,300 | 22.7 |
| Trenholm et al. (2013) | NB | 2007 | 270 | Retention | CV (An Cont.) | Reg, Cul & Prov | 7,408 | 28.9 |
| Trenholm et al. (2013) | NB | 2007 | 256 | Retention | CV (An Cont.) | Reg, Cul & Prov | 14,318 | 17.2 |
| Dias & Belcher (2015) | SK | 2010 | 250 | Retention | CE (One Time) | Prov | - | 64.5 |
| Dias & Belcher (2015) | SK | 2010 | 250 | Retention | CE (One Time) | Reg | - | 117.2 |
| Dias & Belcher (2015) | SK | 2010 | 250 | Retention | CE (One Time) | Reg & Prov | - | 72.5 |
| Rudd et al (2016) | ON | 2011 | 301 | Restoration | CE (An Cont.) | Reg & Prov | 106,253 | 51.14 |
| Rudd et al (2016) | ON | 2011 | 301 | Restoration | CE (An Cont.) | Reg & Prov | 308,875 | 63.11 |
| He et al. (2017) | QC | 2013 | 930 | Restoration | CE (An Cont.) | Reg & Prov | 988,421 | 512 |
| He et al. (2017) | QC | 2013 | 858 | Restoration | CV (An Cont.) | Reg & Prov | 988,421 | 498 |
| Vossler et al. 2020 | QC | 2014 | 1048 | Retention | CV(One Time) | Reg | 62,271,300, | 871 |

Notes:

Prov: Province where study was conducted; QC: Quebec; ON: Ontario; NB: New Brunswick; MB: Manitoba.

WAL: Wetland Acreage Area.

Valuation Format: CV: Contingent valuation; Ce: Choice experiment; An Cont.: Annual contribution, one-time: one time contribution.

Eco Serv: Ecosystem service affected; Reg: regulation services regulate environmental processes such as climate change, water quality and flood control; Prov: provision services.

provide food and raw materials to society, such as fishing and hunting; Cul: cultural services provide existence value of wetlands (non-extractive recreation) to society.

Ch. Acres: Difference between post improvement wetland acres and baseline wetland acres.

WTP: willingness to pay to retain or restore wetlands per household per year in 2017 CAD$ except for the one-time payment, except for the one-time payments.

* 1. **The Canada-United States Wetland Metadata**

Meta-regression involves the application of regression analysis to a pool of comparable empirical estimates (Nelson and Kennedy 2009; Richardson et al. 2015). The first generation of wetland valuation meta-analyses included hundreds of studies from around the world and specified a dollars per area value estimate as the dependent variable (Ghermandi et al. 2010; Brander, Florax, and Vermaat 2006; Woodward and Wui 2001; Brouwer et al. 1999).

These studies report huge heterogeneity in value estimates across the world and apply a range of valuation methods which raises some concerns with these early applications. One concern is with the use of dollar per area values as the dependent variable which may not be appropriate as social values are not linked to a specific surface area of a wetland but rather to people. There are further concerns regarding the commensurability of including value estimates from many different valuation methods such as replacement cost and stated preference as well as studies from such disparate places as the United States and Cameroon which would violate the welfare consistency condition (Nelson and Kennedy 2009; Johnston and Rosenberger 2010; Rosenberger 2010; Boyle and Wooldridge 2018). Another issue is the commodity inconsistency problem, which occurs when the commodity being valued is not the same across studies used for the meta-regression (Vedogbeton and Johnson, 2020). A final concern is that most of these models did not use frameworks that are consistent with economic theory (Moeltner et al. 2019) and key empirical conditions: commodity consistency, welfare consistency, sensitivity to scope and adding up condition (Kling and Phaneuf, 2018; Newbold and Walsh, 2018; Moeltner, 2019). Sensitivity to scope states that willingness to pay to conserve wetlands should increase with the change in wetland area, while the adding up condition specifies that the WTP to achieve a target wetland area should be equal to or less than the sum of incremental WTP estimates from achieving the same wetland area target but in sequential steps (Kling and Phaneuf, 2018; Moeltner, 2019).

We address the welfare consistency condition by including meta-data that used stated preference method to estimate the willingness to pay by households to conserve wetlands in US and Canada (Johnson and Bauer, 2019). For this study, we augment the 8 Canadian studies with a further 15 studies from the United States. From the 8 Canadian studies, we were able to obtain 18 observations, and 25 observations from the US studies. Detailed descriptions of the US and Canadian studies that we used in this study are provided in Tables A2 and A3, respectively (in appendix 1). Also, to ensure that our model is compliant with the commodity consistency principle to produce valid and credible parameter estimates (Vedogbeton and Johnson, 2020) we included a dummy variable which equals 1 if the WTP is for specific ecosystem endpoints, including provisioning, regulating, and cultural ecosystem services. Further, following Kling and Phaneuf (2018) and Moeltner et al. (2019) we estimated our model with functional forms that have the best chance of satisfying the sensitivity to scope and adding up conditions.

**3.2. Descriptive Statistics Results of Study Variables**

We grouped the variables obtained from the database into context-specific and moderator variables. The context-specific variables provide socio-economic and wetland attributes that can support the interpretation of the willingness to pay values to conserve wetlands. The moderator variables describe how the study was conducted, including the valuation method that was employed to elicit willingness to pay responses and the payment characteristics. All the monetary variables from both the US and Canada data studies are converted to 2017 CAD$ per household per year. The summary statistics are for the observations (data) that were used to estimate the meta-regression models.

The average household willingness (WTP) to pay for a wetland conservation program is $137.00/year in Canada; the minimum and maximum WTP are $11.50/household/year and $837.00 /household/year, respectively. The mean wetland area change, which is the difference between policy wetland and baseline acres or the area under WTP valuation, is 92,967 acres. For the US studies, the mean WTP is $36.60/year; the minimum and maximum WTP are $1.50/household/year and $555.60/household/year, respectively. Also, the mean change in wetland area is 1,171 acres for the US data. Figure 1 plots the logarithms of WTP value estimates and changes in wetland program acreage for Canadian and US studies. The figure shows that there is generally a positive correlation between WTP and wetland program acreage and that the Canadian wetland valuation studies have generally valued much larger changes in wetland acreages compared to US studies.

**Figure 1. Relationship between the log of WTP and Log Wetland Acreage Change**

Chart, scatter chart

Description automatically generated

When comparing study characteristics more Canadian studies (44%), on average, informed respondents that the provisioning ecosystem service of wetlands under evaluation was affected than US studies (36%). This is also true for regulating ecosystem services which was 72% in the case of Canadian studies and 56% for the US studies. However, 72% of the US studies informed respondents that cultural ecosystem services were under evaluation compared to 22% of Canadian studies. Also, less wetlands in the Canadian studies were located on forested landscapes (44%) compared to the US studies (56%). Again, almost the same proportion of the Canadian studies (50%) and US (44%) were conducted at the local level, where the targeted respondents in the stated preference study were at the sub-province or sub-state level.

In terms of the moderator variables, about 28% of the studies in the US used a choice experiment for valuation which is greater than the Canadian proportion of 17%. Also, fewer studies in Canada used voluntary contribution payment mechanism and lump sum to elicit willingness to pay responses (17% and 6%, respectively) than in the US studies (36% in both cases). Fewer studies in the US were published in peer reviewed journals (29%) compared to the Canadian studies (89%). The summary statistics are provided in Table 2.

The summary statistic differences of the variables in the US and Canadian data suggest that using US only studies on willing to pay for wetland conservation by households to infer similar values in Canada through a benefit transfer approach, might produce unreliable estimates due to the following characteristics. In particular, wetland changes, on the average, in the Canadian studies are significantly greater compared to the US studies which might mean that Canada only studies may be appropriate in valuing big changes in wetland acreage. Therefore, it may be useful to combine US and Canadian studies to infer values of wetland acreage changes, including smaller area changes, in Canada.

**Table 2. Variable description and sample statistics**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Canada (N=18)** | | | **USA (N=25)** | | |
|  |  | **Mean (SD)** | **Min** | **Max** | **Mean (SD)** | **Min** | **Max** |
| Dependent Variable | Log (WTP) | 4.92 (1.44) | 2.45 | 6.73 | 3.60(1.42) | 0.40 | 6.32 |
| **Context** |  |  |  |  |  |  |  |
| Acreage change | Log (Difference between post improvement wetland acres and baseline wetland acres) | 11.44(2.53) | 8.34 | 17.95 | 7.07(2.29) | 3.37 | 11.10 |
| Baseline Acres | Log (Baseline wetland acres) | 9.40(6.36) | 0.00 | 17.54 | 9.10(2.34) | 0.00 | 12.30 |
| Income | Log (target population income in Canadian $) | 11.18(0.23) | 10.70 | 11.53 | 11.27(0.26) | 10.91 | 11.75 |
| Cultural | 1 = cultural function affected | 0.22(0.43) | 0.00 | 1.00 | 0.72(0.46) | 0.00 | 1.00 |
| Forest | 1 = forested wetland | 0.44(0.51) | 0.00 | 1.00 | 0.56(0.51) | 0.00 | 1.00 |
| Local | 1 = target population at sub-state level | 0.50(0.51) | 0.00 | 1.00 | 0.44(0.51) | 0.00 | 1.00 |
| Provision | 1 = provisioning function affected | 0.44(0.51) | 0.00 | 1.00 | 0.36(0.49) | 0.00 | 1.00 |
| Regulation | 1 = regulating function affected | 0.72(0.46) | 0.00 | 1.00 | 0.56(0.51) | 0.00 | 1.00 |
| Year | Log (year of data collection - oldest year +1) | 2.90(0.19) | 2.40 | 3.18 | 2.18(1.86) | 0.00 | 7.61 |
| **Moderator** |  |  |  |  |  |  |  |
| CE | 1=elicitation method=choice experiment | 0.17(0.38) | 0.00 | 1.00 | 0.28(0.46) | 0.00 | 1.00 |
| Lumpsum | 1=payment frequency=lump sum (single payment) | 0.06(0.24) | 0.00 | 1.00 | 0.36(0.49) | 0.00 | 1.00 |
| Voluntary | 1=payment mechanism=voluntary contribution | 0.17(0.38) | 0.00 | 1.00 | 0.36(0.49) | 0.00 | 1.00 |
| Peer Review | 1=study was peer-reviewed | 0.89(0.32) | 0.00 | 1.00 | 0.28(0.46) | 0.00 | 1.00 |

SD denotes standard deviation; N denotes number of observations.

**4.1. Meta-Regression Econometric Model**

We used a random intercept meta-regression model to explain the variation in the willingness to pay to conserve wetlands in the US and Canada, to account for multiple observations per study, (Nelson and Kennedy, 2008). The model is represented as equation 1:

where: denotes the willingness to pay to conserve wetlands for the ith observation; is a vector of explanatory variables, including the baseline wetland area and quantity area change; is model parameters to be estimated; the stochastic error term for the ith observation, which is assumed to be normally distributed with mean 0 and a constant variance (which accounts for variation in wetland values due to differences between individual observations; stochastic error term for the jth study, which is assumed to be normally distributed with mean 0 and a variance (and accounts for variation in wetland values due to differences between study observations; is functional form.

We will test if the random intercept model is appropriate for our study or the null hypothesis that (in equation 1) is significantly different from zero using a likelihood ratio test (Dias and Belcher, 2015) with the “ranova” function in the “lmer” package in R statistical software; we will use an ordinary least square if the null hypothesis is rejected. Also, we will use a heteroscedastic consistent estimator for equation 1 if we reject the null hypothesis that the observation level model error is homoscedastic or has constant variance; a non-constant error variance can affect the reliability of estimated standard errors of model parameters and, therefore, the credibility of model inferences. Although multicollinearity will not affect the reliability of estimated standard errors of model parameters, it could inflate them. As a result, variables that have variance inflation factors (VIF) of more than 10 will not be used to estimate the model. Variables with high VIF’s could be sources of multicollinearity in the model.

The choice of functional form for equation 1 will be instrumental in determining if the estimated model will conform to economic theory and/or whether the meta-regression value function can be useful for benefit transfer (Kling and Phaneuf, 2018; Moeltner, 2019). Our chosen functional form must be consistent to two theoretical constructs of sensitivity to scope and adding up, which are important in assessing the validity of benefit transfer applications (Kling and Phaneuf, 2018; Newbold and Walsh, 2018; Moeltner, 2019). However, according to Kling and Phaneuf (2018), the validity of sensibility scope could provide a better judgement of the usefulness of the meta-regression to benefit transfer compared to the adding up criteria. Adding up is “a conceptually difficult test to implement” (Kling and Phaneuf, 2018) and empirical tests conducted to date using real goods payments and private goods fail to show consistency with adding up (Kling and Phaneuf, 2018). In response we will estimate 2 models and choose the one that satisfies sensitivity to scope and is consistent to the assumptions of utility theory, in particular, diminishing marginal utility. Also, we will show if our chosen model satisfies the adding up condition.

The first model (which we call model A) will use a log-log linear functional form which is given as equation 2:

where: is the natural logarithm of baseline wetland area for the ith observation and is the associated parameter to be estimated; is the natural logarithm of the quantity acreage change and is the associated parameter to be estimated; all other variables have already been defined for equation 1.

The coefficient of the log of baseline wetland acres, if negative, shows a diminishing marginal utility of additional improvements (or wetland acreage increase) which is expected from economic utility theory (Kling and Phaneuf, 2018). Moeltner et al. (2019), estimated this functional form in a meta-regression study and found severe departure from the adding up condition. We expect the coefficient of log wetland acreage change in the main model (full, unrestricted, model: equation 2) to be significant (at least at 10% level); when this is not the case, we will estimate two other versions of model A: i) equation 1 will include only log baseline acreage and log wetland acreage change as independent variables (restricted), and ii) equation 1 will exclude some of the independent variables that were not significant (at 10% level) in the main model (semi-restricted).

The second model (model B) in equation 3 will also follow a log-log functional form. However, unlike equation 2, the dependent variable is the log of willingness to pay minus the log of quantity acreage change.

The transformation in the dependent variable is necessary to convert the willingness to pay values into the same units because of the differing values in the quantity acreage change (Kling and Phaneuf, 2018). Moeltner et al. (2019) has estimated a meta-regression model with this function form and could not find serious violation of the adding up condition. The independent variables include the log of baseline wetland acreage. Also, the same procedure will be followed to estimate other versions of model B when the coefficient of log wetland acreage is not significant (at least 10% level).

Further, following Moeltner et al. (2019) we will test the validity of the adding up condition for the estimated models. Specifically, we will apply the estimated models to four wetland scenarios, namely i) wetlands located in forested landscapes and valuation study was at the sub-province or state level, ii) wetlands located in forested landscape and valuation study was at the province or state level, iii) wetlands located in non-forested landscape and valuation study was at the state level, and v) wetlands located in non-forested landscape and valuation study was at the sub-province or state level. For each scenario, we calculated the total WTP to conserve wetland area given a hypothetical change from baseline (10,000acres) to new state (10,050acres); the incremental WTP to conserve wetlands from baseline (10,000acres) to new state (10,030acres); and incremental WTP to conserve wetlands from baseline (10,030acres) to new state (10,050acres). We defined Lnyear as (log (2017-1991 +1)), lumpsum = 0 (so that we can interpret WTP in per year units), Lninc was defined at the sample mean, volunt =1, choice experiment = 1, peer review = 1; the variables are described in Table 2.

**4.2. Benefit Transfer Error**

We discuss the steps that will be used to estimate the benefit transfer errors from our estimated meta-regression models and mean value transfer when estimating Canadian wetland values. The transfer errors will be in-sample because the predicted wetland values are for Canadian observations that are used to estimate the models. We will focus on the Canadian observations because we want to compare the degree of benefit transfer error from using a US-Canada data and US only data meta-regression models.

We used a leave one out cross validation (LOOCV) method will be used to estimate the prediction error (root mean squared error) of our estimated models. The LOOCV, which is an n-fold cross validation (where n is the number of observations of the data) goes through the following steps: i) data would be divided into n folds or observations, ii) In the ith iteration, a fold (one observation) is selected as the test data, and the model is estimated using the remaining n-1 folds. In this stage, since n =1, the root mean squared error (RMSE) statistic will be estimated using this equation: , iii) the process is repeated for all the n observations. In the end, the number of estimated RMSE will be the same as number of observations of the data. For the US-Canada data (43 observations), after estimating the 43 RMSE statistics, we will use the 16 Canadian observations to estimate the mean RMSE statistic.

For the US only data (25 observations) we will not have Canadian data to conduct the LOOCV. Therefore, we will use the estimated US model to predict each Canadian wetland value. We will estimate the RMSE, using the formula above, for the 16 Canadian observations; then we will estimate the mean RMSE statistic.

* 1. **Economic Loss Associated with Canadian Prairie Habitat Joint Venture Wetland Area Loss**

We apply the model with the lowest meta-regression benefit transfer error, the US-Canada, or US only model, to predict the total economic loss for wetland area loss, between 2001 to 2011, in Saskatchewan, Alberta and Manitoba PHJV landscapes. The wetland area loss over the 10-year period for the 3 provinces are 112,574 acres, 28,252 acres and 11,734 acres for Saskatchewan, Alberta, and Manitoba, respectively. The mean, minimum and maximum wetland acre change (wetland area loss) for the Canadian observations in the US-Canada model are 92,967 acres, 3,000 acres and 62,271,300 acres, respectively; this means that the PHJV provincial wetland area loss information is plausible. Moreover, we focused on the period 2001 to 2011 and the PHJV landscape in the three provinces because of the available data on wetland area loss.

For a given wetland area loss in a province, the meta-regression model will predict the WTP ($/household/year) of an average household to restore the wetland area loss; the household willingness to pay could be construed as the economic loss to the household for the loss of the wetland area. To estimate the economic loss of the wetland area loss in a province, we will multiply the total number of households in the province by the predicted household WTP to restore the wetland area loss; the number of households[[2]](#footnote-2) are Saskatchewan (432,652), Alberta (1,527,675), and Manitoba (489,050). Apart from wetland acreage change, which will be equal to wetland area loss for the three provinces, we need information on the other independent variables in the estimated meta-regression model. We will include the following variables and assumptions in the analysis:

|  |  |  |  |
| --- | --- | --- | --- |
| **Variables** | **Saskatchewan** | **Alberta** | **Manitoba** |
| **Context** |  |  |  |
| Log (Acreage Change) | Log( | -0.159\* (0.084) |  |
| Log (Acreage) | 0.022 (0.053) | 0.161 (0.213) |  |
| Log (Year) | Log(2017-1999+1) | Log(2017-1999+1) | Log(2017-1999+1) |
| Local | 0 | 0 | 0 |
| US | 0 | 0 | 0 |
| Provision | 1 | 1 | 1 |
| Regulation | 1 | 1 | 1 |
| Cultural | 1 | 1 | 1 |
| Forest | 0 | 0 | 0 |
| Log(Income) |  |  |  |
| **Moderator** |  |  |  |
| Voluntary |  |  |  |
| Lumpsum |  |  |  |
| Choice Experiment |  |  |  |
| Peer Review |  |  |  |

Notes:

1. Log (Acreage change) is the log (wetland area loss between 2001 and 2011).
2. Log (Acreage) is the log (wetland acres in 2001).

3) Logarithm of year is log (2017 - 1991 +1).

4) local =0 because the prediction is done for wetlands at provincial level.

5) The wetlands produced provisioning, regulating and cultural ecosystem services.

6) Log(income) is the logarithm of the mean total income (2017$) for Saskatchewan, Alberta, and Manitoba.

7) Wetlands are in non-forested regions.

8) The values for Voluntary, Lumpsum, Choice experiment, and Peer review are the means of the variables in the Canadian portion of the US-Canada dataset.

* 1. **Meta-Regression Results**

We will first present the results of the preferred model using the US-Canada data, followed by that of the model using the US only data. The random coefficient model is appropriate for all the estimated models except model 2 (unrestricted version using the US data) because the null hypothesis that the observation level random error component of equation is significantly different from zero is rejected.

We chose model 1, the semi-restricted model, because it provided the best fit to the study data than model 2. The Akaike information criteria (AIC=116) for model 1, (Table 4), is lower than that of all the other estimated versions of Model 1 (Table A5 in appendix) and all the estimated versions of model 2 (A6 in appendix). The adjusted coefficient of determination of model 1 (0.93) shows that about 93% of the variation in the dependent variable is explained by the model. While this is a very high adjusted R square, Vedogbeton and Johnson (2020) also estimated an adjusted R square of about 95% in their estimated meta-regression model. The null hypothesis of constant variance of the model error term (homoscedasticity) was not rejected even at the 10% level. The variance inflation factors for all the independent variables are less than 2 which shows that multicollinearity is not a problem in the model.

The sensitivity of scope criteria is not rejected in model 1 because the coefficient (0.46) of the log (quantity acreage change) is positive and significant at the 1% level; it means that a 1% increase in acreage change would cause a 0.46% increase in willingness to pay to conserve the acreage change. Also, the model did not uphold the law of diminishing marginal utility in wetland acreage, because of the positive coefficient of the log of baseline acreage (0.03), but it is not significant at the 10% level. Also, the model shows that the value of wetlands has decreased by about 30% since 1991. Also, the value of wetlands estimated at the local level was more than those estimated at the province level by a factor of 3.22[[3]](#footnote-3). Wetlands that provide provisioning services are less valuable than wetlands that do not by a factor of 2.23; and wetlands that provide regulation services are more valuable than wetlands without regulation services by a factor of 1.9. Moreover, wetlands that are in the US are more valuable than those in the US, for this study, by a factor of 1.7.

**Table 4. Model 1 Meta-regression results (US-Canada Combined Data)**

|  |  |  |
| --- | --- | --- |
|  | **Model 1** | |
|  | **Semi-Restricted**  **US-Canada Data** | **Unrestricted**  **US Data** |
| Dependent Variable: Log (WTP) |  |  |
| **Context** |  |  |
| Log (Acreage Change) | 0.457\*\*\* (0.115) | -0.159\* (0.084) |
| Log (Acreage) | 0.022 (0.053) | 0.161 (0.213) |
| Log (Year) | -0.270\*\* (0.125) | -0.398 (0.290) |
| Local | 1.444\*\* (0.585) | 1.852\* (1.087) |
| US | 0.981 (0.658) |  |
| Provision | -1.174\*\*\* (0.439) | -1.039 (1.185) |
| Regulation | 1.061\*\* (0.484) | -1.903 (1.380) |
| Cultural | 0.467 (0.365) | 0.367 (1.104) |
| Forest | -0.845 (0.574) | 1.292\*\*\* (0.348) |
| Log(Income) | 1.370 (1.225) | 0.727 (2.280) |
| **Moderator** |  |  |
| Voluntary | -0.275 (0.673) | -0.664 (1.226) |
| Lumpsum | 0.715 (0.557) | -1.552 (1.234) |
| Choice Experiment | -0.481 (0.425) | -2.505\* (1.457) |
| Peer Review |  | 3.278\*\* (1.521) |
| Constant | -15.982 (14.146) | -3.082 (25.732) |
| Number of Observations | 43 | 25 |
| Log Likelihood | -41.997 | -18.166 |
| Akaike Inf. Crit. | 115.994 | 68.332 |
| Log-likelihood Test | 15\*\*\* | 6\* |
| Adjusted R-Square | 0.94 | 0.97 |

\*\*\*, \*\*, \* denotes significance at 1%, 5% and 10%, respectively; WTP denotes willingness to pay; values in parenthesis are standard errors.; peer review was dropped because of VIF of 11.

The adding up condition was violated for the model for all scenarios (Table A9 in appendix) since the sum of the WTP to conserve 30 acres (from 10,000 acres to 10,030) of wetlands and 20 acres (10,030 acres to 10,050 acres) of wetlands was greater than the WTP to conserve 50 acres (from 10,000 acres to 10,050 acres). The full description of the scenarios and the streps we used to evaluate the adding up test is provided in section 4.1.

Regarding the US only model, we chose model 1 (unrestricted) because its AIC (Table 3) is the lowest among the other estimated versions of Model 1 (appendix A7) and all the estimated versions of Model 2 (Appendix A8). The model explained about 97% of the variation in the natural log of WTP. Also, the null hypothesis of homoscedasticity of the error term was not rejected even at the 10% level; multicollinearity was not a problem because the variance inflation factors for all the independent variables were less than 10. The diminishing marginal utility assumption is not violated because the coefficient of the log of acreage is negative, and it is significant at the 10% level. This result can be interpreted that a 1% increase in the acreage will cause about 1.9% increase in willingness to pay to conserve that acreage change. However, the sensitivity of scope assumption is not validated because the coefficient of log acreage change is negative; it is also not significant even at the 10% level. Also, a 1% increase in income would cause about 1.3% increase in willingness to pay to conserve wetlands. Wetland values that are estimated at the local level are more valuable than those estimated at the state level by a factor of 5.4; the effect is significant at the 10% level. Wetlands that are in forested landscapes are about 2.6 times more valuable than those in other landscapes at the 1% significance level. Wetlands in peer reviewed studies are about 25 times more valuable than those in non-peer reviewed studies at the 1% level. Wetlands whose values are estimated with a choice experiment method are about 11 times less valuable than those using other contingent valuation method at the 10% level. Moreover, the adding up condition was violated since the sum of WTP to conserve 30 wetland acres (10,000 acres to 10,030 acres) and 20 acres (10,030 acres to 10,050 acres) was less than the WTP to conserve 50 acres (10,000 acres to 10,050 acres) in all the scenarios (Table A9 in appendix).

* 1. **Meta-Function Benefit Transfer Errors**

We performed a Leave One Out Cross Validation (LOOCV) to estimate the root mean square error of the meta-regression models (US-Canada and US only data models) and the root mean square mean value transfer error when applied to estimate the value of Canadian wetlands (in-sample). The mean value transfer provides a relatively faster and cheaper method to assign economic value to wetlands using $/acre of similar wetlands from the literature. Full details of the LOOCV are provided in section 4.2. The results are provided in Table 5.

**Table 5. Cross Validation Transfer Errors Results**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Transfer Error Statistic** | **Root Mean Squared Error**  **Model 1 (Semi-restricted)**  **US-Canada Model** | | **Root Mean Squared Error**  **Model 1 (Full)**  **US only Model** | |
|  | Meta-regression | Mean value | Meta-regression | Mean value |
| Mean | 0.66 | 1.29 | 2.26 | 1.70 |
| Median | 0.26 | 1.30 | 0.93 | 1.07 |
| SD | 0.75 | 0.83 | 2.28 | 1.68 |
| Minimum | 0.04 | 0.12 | 0.34 | 0.02 |
| Maximum | 2.36 | 3.36 | 6.54 | 4.34 |
|  |  |  |  |  |

SD denotes standard deviation.

The results show that the mean meta-regression error predicting the values of Canadian wetlands using the US-Canada model is 57% (with a minimum and maximum errors of 4% and 207%, respectively); the median error is 32%. Also, mean value transfer error is 137% whilst the median is 127%; the minimum and maximum mean value transfer errors are 30% and 337%, respectively.

Regarding the meta-regression for the US data model, the mean and median meta-regression transfer errors are 316% and 361%, respectively, when predicting Canadian wetland values; the minimum and maximum transfer errors are 22% and 542%, respectively. Also, the mean and median mean value transfer errors are 241% and 238%, respectively; the minimum and maximum mean value transfer errors are 8% and 476%, respectively.

* 1. **Results of the Empirical Application to Canadian Prairie Habitat Joint Venture Landscape Wetland Loss**

There are a total of 21 Saskatchewan RMs within the study PHJV landscape. The average wetland acreage loss, between 2001 and 2011, in the study landscape is 5,361 acres with a standard deviation of 4,062 acres; the minimum and maximum wetland acreage loss in the same period are 928 acres and 16,206 acres, respectively (Table 6). Moreover, the average WTP in the Saskatchewan PHJV landscape is $14.54/household/year with a standard deviation of $5.40/household/year; the minimum and maximum WTP in the location are $6.70/household/year and $26.00/household/year, respectively. There is a positive relationship between WTP and wetland acreage loss, which shows that households in the Saskatchewan PHJV landscape will be willing to pay more to conserve greater wetland acres (Figure 2). Our meta-regression results showed that lives outside the Saskatchewan PHJV locations will be willing to pay less to retain/restore the wetland acreage loss contrast compared to households residing in the locations.

Table 7 reports the total economic loss to the three Canadian prairie provinces associated with wetland acreage loss in the PHJV Canadian Prairie landscapes. Details on how the economic loss was calculated are provided in section 4.3.

**Table 7. Estimates of Economic Loss Associated with Wetland Acreage Loss in the Canadian Prairie PHJV Landscapes, 2001 – 2011.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Province** | **Acre Change** | **WTP ($/household/yr)** | **Number of Households** | **TWTP (scale?)** |
| Saskatchewan | 112,574 | 15.73 | 432,625 | 6,806,404 |
| Alberta | 28,252 | 6.55 | 1,527,675 | 10,012,048 |
| Manitoba | 11,734 | 4.09 | 489,050 | 2,002,414 |

WTP = Willingness to pay; TWTP = Total willingness to pay

.

The total economic loss associated with the PHJV wetland acreage loss highest in Alberta ($10 million /year) followed by Saskatchewan ($6.8 million /year) and then Manitoba ($2.0 million /year). The total economic loss is driven mainly by the number of households in the provinces which is highest in Alberta. For the entire Canadian Prairie, the total economic loss is $18.8 million /year.

**6. Discussion and Conclusion**

There is limited information estimating the economic values of wetlands in Canada. The problem is exacerbated when we narrow the search to specific wetland ecosystems such as freshwater wetlands which is the most common form of wetlands in Canada. The lack of information on wetland valuation studies may present problems to wetland conservationist and policy makers who may be interested in evaluating the social value of wetland conservation vis a vis the monetary benefits from conserving wetlands.

We estimated a meta-regression value function using US and Canada stated preference wetland valuation studies and US only studies and compared their fit (in terms of root mean squared prediction errors) to predicting Canadian wetland values (willingness to pay, $/household/year, by households to conserve wetlands). First, we found that, compared to mean value benefit transfer error, the mean transfer error from the estimated meta-regression model (using US-Canada data) is about 80% lower and 95% for median transfer error. The performance of our model over a mean value benefit transfer is higher than what has been reported in the literature; Rosenberger and Loomis (2017) using a survey of meta-regression studies report a 15% difference between meta-regression (45%) and mean value benefit transfer errors (30%). Again, our estimated meta-regression transfer error, which is 57% is about 12% higher than what is reported in Rosenberger and Loomis (2017) but about 2 times lower than the estimates in Brouwer and Pinto (2019). Moreover, the mean transfer error from the meta-regression model (with US-Canada data) is about 263% lower than the mean error when using the meta-regression model (with US data); Johnson and Thomasin (2010) found a similar result, and this underscores the need to use US only wetland valuation studies with caution when predicting Canadian wetland values. A better approach, when there are very few wetland valuation studies in Canada, will be to combine data from the US and Canada as we have showed in this study to predict Canadian wetland values.

Moreover, our estimated meta-regression model (with US-Canada data) have identified important variables which could guide applied benefit transfer practitioners in bridging the dissimilarities between wetland valuation study and policy sites. Our study showed that the variables log acreage, log acreage change, wetland study at the sub-province or sub-state level (local), provisioning and regulating ecosystem services provide the greatest guidance. Study sites are original wetland valuation studies whiles policy sites are the new wetlands we want to value using information from study sites. We also found that wetlands in the US are valued more than those in Canada by households.

We applied the estimated meta-regression model (with US-Canada data) to estimate the economic loss associated with wetland acreage loss, between 2001 and 2011, to households in Saskatchewan RMs where PHJV target landscapes are located. We found that the average WTP to conserve wetlands per household was $14.5/household/year, and the total economic loss to households was $3,390/year. Moreover, the WTP to conserve wetlands increased with the wetland acreage change (area of wetland to conserve) with the WTP values inversely related to the distance of their residences to the wetland. Again, the total economic loss associated with the wetland acreage loss to households in the three provinces are Alberta ($10,012,048), Saskatchewan ($6,806,404/year) and Manitoba (2$2,002,414/year). The estimated economic loss to the provinces from the wetland area loss are potential lower bound values in the plausible set of economic loss estimates; this is because wetlands are very complicated ecosystems and multifunctional in terms of the ecosystem services, they may produce to benefit society. However, the estimates above serve as a starting point in providing a basis for society to compare some of the budgets they may design to conserve wetlands.

The number of wetland valuation studies that were used in our study was 43; 17 observations from 8 Canadian studies and 25 observations from 15 studies). We feel the small number of observations in our study may not provide a strong basis to make general inferences Therefore, our results must be interpreted with this caution. However, we make contributions to the wetland valuation literature by providing an approach to estimate wetland values and implying the method to estimate wetland values in the Canadian PHJV; which is an important breeding ground for waterfowls.

We strongly encourage future studies to conduct more stated preference wetland valuation studies in Canada. When this is done, it will provide researchers enough information to build robust meta-regression value functions which can be used to predict the values of wetlands; meta-regression, in the absence of original studies, have been shown to be the best method to estimate the values of wetlands.

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**Appendix A**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Author | | Year | | Type | | Target Population | | Wetland type | | BA | PA | | WTP | |
| Whitehead & Blomquist | | 1991 | | J | | All KY HHs | | Freshwater, forested | | 36,000.00 | 41,000.00 | | 19.00 | |
| Loomis et al. | | 1991 | | BC | | All CA HHs | | Freshwater, unspec. | | 27,000.00 | 85,000.00 | | 258.00 | |
| Loomis et al. | | 1991 | | BC | | All CA HHs | | Freshwater, unspec. | | 85,000.00 | 125,000.00 | | 426.00 | |
| Beran, L.J. | | 1995 | | D | | All SC HHs | | Freshwater, forested | | 6,000.00 | 8,500.00 | | 36.00 | |
| Beran, L.J. | | 1995 | | D | | All SC HHs | | Freshwater, forested | | 6,000.00 | 8,500.00 | | 27.00 | |
| Beran, L.J. | | 1995 | | D | | All SC HHs | | Freshwater, forested | | 6,000.00 | 8,500.00 | | 33.00 | |
| deZoysa | | 1995 | | D | | Selected MSAs, OH | | Freshwater, unspec. | | 10,000.00 | 13,000.00 | | 109.00 | |
| Blomquist & Whitehead | | 1998 | | J | | All KY HHs | | Freshwater | | 3,468.00 | 3,968.00 | | 3.00 | |
| Blomquist & Whitehead | | 1998 | | J | | All KY HHs | | Freshwater, forested | | 69,580.00 | 70,080.00 | | 8.00 | |
| Blomquist & Whitehead | | 1998 | | J | | All KY HHs | | Freshwater, forested | | 21,716.00 | 22,216.00 | | 6.00 | |
| Blomquist & Whitehead | | 1998 | | J | | All KY HHs | | Freshwater, forested | | 908.00 | 1,408.00 | | 19.00 | |
| MacDonald et al. | | 1998 | | J | | Atlanta region, GA | | Freshwater, unspec. | | 212,378.00 | 212,708.00 | | 108.00 | |
| Mullarkey & Bishop | | 1999 | | CP | | All WI HHs | | Freshwater, forested | | 219,890.00 | 220,000.00 | | 64.00 | |
| Poor | | 1999 | | J | | All NE HHs | | Freshwater, unspec. | | 34,000.00 | 50,000.00 | | 47.00 | |
| Poor | | 1999 | | J | | All NE HHs | | Freshwater, unspec. | | 34,000.00 | 75,000.00 | | 42.00 | |
| Poor | | 1999 | | J | | All NE HHs | | Freshwater, unspec. | | 34,000.00 | 100,000.00 | | 47.00 | |
| Whitehead et al. | 2009 | | J | | Selected counties, MI | | Freshwater, unspec. | | 9,000.00 | | | 10,125.00 | | 73.00 |
| Awondo et al. | | 2011 | | J | | Maumee Bay SP, OH, visitors | | Freshwater, unspec. | | 0.00 | 2,499.00 | | 193.00 | |
| Newell & Swallow | 2013 | | J | | Two townships, RI | | Freshwater, forested | | 5,838.00 | | | 5,867.00 | | 9.00 |
| Newell & Swallow | | 2013 | | J | | Two townships, RI | | Freshwater, forested | | 5,822.00 | 5,867.00 | | 12.00 | |
| Newell & Swallow | 2013 | | J | | Two townships, RI | | Freshwater, forested | | 5,807.00 | | | 5,867.00 | | 16.00 |
| Johnson et al | 2015 | | TR | | Maine | | Freshwater, unspec. | | 4000 | | | 4700 | | 8.8 |
| Johnson et al | 2016 | | J | | Maine | | Freshwater, unspec. | | 4000 | | | 4700 | | 92.7 |

**Table A1. Description of US studies used in this study.**

Notes: BA is base wetland acreage; PA is policy wetland acreage; WTP is willingness to pay; j is journal article; BC is book chapter; CP is conference paper; TR is technical report; D is dissertation

**Table A2. Description of Canadian studies used in this study.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Author | Year | Type | Target Population | Wetland type | BA | PA | WTP |
| Tkac | 2002 | D | Southern Ontario | Freshwater, unspec | 4200 | 8400 | 79.22 |
| Ayokunle | 2003 | D | Saskatchewan | Freshwater, unspec | 0 | 555975 | 62.4 |
| Pattisson et al | 2011 | J | Manitoba | Freshwater, unspec | 945184 | 1044702 | 295.1 |
| Pattisson et al | 2011 | J | Manitoba | Freshwater, unspec | 945189 | 1084782 | 301.65 |
| Pattisson et al | 2011 | J | Manitoba | Freshwater, unspec | 945189 | 1125461 | 308.31 |
| Pattisson et al | 2011 | J | Manitoba | Freshwater, unspec | 945189 | 1206820 | 321.46 |
| Pattisson et al | 2011 | J | Manitoba | Freshwater, unspec | 945189 | 1355977 | 347.8 |
| Trenholm et al | 2013 | J | Southern New Brunswick | Freshwater, forested | 0 | 14318 | 14.6 |
| Trenholm et al | 2013 | J | Southern New Brunswick | Freshwater, forested | 0 | 11300 | 19.38 |
| Trenholm et al | 2013 | J | Southern New Brunswick | Freshwater, forested | 0 | 7408 | 24.7 |
| Trenholm et al | 2013 | J | Southern New Brunswick | Freshwater, forested | 0 | 5884 | 31.56 |
| Rudd et al | 2016 | J | Southern Ontario | Freshwater, forested | 1307159 | 1616034 | 58.00 |
| Rudd et al | 2016 | J | Southern Ontario | Freshwater, forested | 1307159 | 1413412 | 47.00 |
| Lantz et al. | 2013 | J | Greater Toronto Area | Freshwater, unspec | 11997 | 18520 | 431.3 |
| Lantz et al. | 2013 | J | Greater Toronto Area | Freshwater, unspec | 11997 | 17520 | 436.7 |
| He et al | 2017 | J | Southern Quebec | Freshwater, unspec | 988422 | 1976843 | 482 |
| He et al | 2017 | J | Southern Quebec | Freshwater, unspec | 988422 | 1976843 | 465 |
| Vossler et al. | 2020 | J | Quebec | Freshwater, unspec | 41514200 | 103785500 | 836 |

Notes: BA is base wetland acreage; PA is policy wetland acreage; WTP is willingness to pay which is measured in C$ in the year of study per household per year;

j is journal article; BC is book chapter; CP is conference paper; TR is technical report; D is dissertation

**Table A3. Ecosystem Services Questions in WTP Surveys**

**Table A4. Model 1 Meta-regression results (US-Canada Data)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Model 1: US-Canada Data** | | | | | | |
|  | **(Restricted)** | **(Semi-Restricted A)** | | | **(Semi-Restricted B)** | **(Unrestricted)** |  | |
| Dependent Variable: Log (WTP) |  |  |  |  | |  |
| **Context** |  |  |  |  | |  |
| Log (Acreage Change) | 0.246\*\*\* (0.057) | 0.232\*\*\* (0.062) |  | 0.457\*\*\* (0.115) | | 0.425\*\*\* (0.122) |
| Log (Acreage) | 0.084\* (0.051) | 0.053 (0.044) |  | 0.022 (0.053) | | 0.013 (0.055) |
| Log (Year) |  |  |  | -0.270\*\* (0.125) | | -0.284\*\* (0.133) |
| Local |  |  |  | 1.444\*\* (0.585) | | 1.574\*\* (0.642) |
| US |  |  |  | 0.981 (0.658) | | 1.060 (0.715) |
| Provision |  |  |  | -1.174\*\*\* (0.439) | | -1.394\*\* (0.542) |
| Regulation |  |  |  | 1.061\*\* (0.484) | | 0.917 (0.603) |
| Cultural |  | -0.808\*\* (0.337) |  | 0.467 (0.365) | | 0.531 (0.366) |
| Forest |  |  |  | -0.845 (0.574) | | -0.826 (0.612) |
| Log(Income) |  |  |  | 1.370 (1.225) | | 1.233 (1.323) |
| **Moderator** |  |  |  |  | |  |
| Voluntary |  | -0.933\* (0.525) |  | -0.275 (0.673) | | 0.024 (0.870) |
| Lumpsum |  | 0.709 (0.504) |  | 0.715 (0.557) | | 0.498 (0.663) |
| Choice Experiment |  | -1.125\*\*\* (0.419) |  | -0.481 (0.425) | | -0.419 (0.427) |
| Peer Review |  | 0.264 (0.409) |  |  | | 0.480 (0.711) |
| Constant | 1.359\*\* (0.652) | 2.365\*\*\* (0.628) |  | -15.982 (14.146) | | -14.285 (15.233) |
| Number of Observations | 43 | 43 |  | 43 | | 43 |
| Log Likelihood | -62.990 | -51.026 |  | -41.997 | | -41.231 |
| Akaike Inf. Crit. | 135.981 | 122.051 |  | 115.994 | | 116.462 |
| Log-likelihood Test | 18\*\*\* | 12\*\*\* |  | 15\*\*\* | | 15\*\*\* |

\*\*\*,\*\*,\*denotes significance at 1%, 5% and 10%, respectively; WTP denotes willingness to pay.

**Table A5. Model 2 Meta-regression results (US-Canada Data)**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Model 2: US-Canada Data** | | |
|  | **(Restricted)** | **(Semi-Restricted)** | **(Unrestricted)** | |
|  |  |  |  | |
| **Context** |  |  |  | |
| Log (Acreage) | -0.099 (0.109) | 0.042 (0.133) | -0.064 (0.068) | |
| Log (Year) |  |  | -0.218 (0.169) | |
| Local |  |  | 2.101\*\*\* (0.807) | |
| US |  |  | 3.442\*\*\* (0.641) | |
| Provision |  |  | -1.703\*\* (0.687) | |
| Regulation |  |  | 1.583\*\* (0.746) | |
| Cultural |  |  | -2.188\*\*\* (0.686) | |
| Forest |  | 0.083 (0.590) | 0.996\*\* (0.463) | |
| Log(Income) |  |  | 3.198\*\* (1.598) | |
| **Moderator** |  |  |  | |
| Voluntary |  | -10.018\*\*\* (1.403) | 0.270 (1.106) | |
| Lumpsum |  | 5.668\*\*\* (2.014) | 1.732\*\* (0.773) | |
| Choice Experiment |  | 0.140 (0.657) | -0.244 (0.560) | |
| Peer Review |  | -4.776\*\*\* (1.043) | -0.242 (0.884) | |
| Constant | -3.597\*\*\* (1.158) | -1.162 (1.581) | -42.614\*\* (17.827) | |
| Number of Observations | 43 | 43 | 43 | |
| Log Likelihood | -95.539 | -78.323 | -48.495 | |
| Akaike Inf. Crit. | 199.079 | 174.646 | 128.990 | |
| Log-likelihood Test | 11\*\* | 17\*\*\* | 23\*\*\* | |
|  |  |  |  | |

\*\*\*,\*\*,\*denotes significance at 1%, 5% and 10%, respectively; WTP denotes willingness to pay.

**Table A6. Model 1 Meta-regression results (US Data)**

|  |  |  |  |
| --- | --- | --- | --- |
|  | | | |
|  | **Model 1: US Data** | | |
|  | **(Restricted)** | **(Semi-Restricted A)** | **(Unrestricted)** |
|  | | | |
| Dependent Variable: Log (WTP) |  |  |  |
| **Context** |  |  |  |
| Log (Acreage) | -0.041 (0.093) | -0.151 (0.094) | -0.159\* (0.084) |
| Log (Acreage Change) | 0.374\*\* (0.150) | 0.392\*\* (0.199) | 0.161 (0.213) |
| Log (Year) |  |  | -0.398 (0.290) |
| Local |  |  | 1.852\* (1.087) |
| Provision |  | -1.438 (1.040) | -1.039 (1.185) |
| Regulation |  | 0.256 (1.122) | -1.903 (1.380) |
| Cultural |  | -0.657 (1.274) | 0.367 (1.104) |
| Forest |  | 1.108\*\*\* (0.387) | 1.292\*\*\* (0.348) |
| Log(Income) |  | -0.728 (2.637) | 0.727 (2.280) |
| **Moderator** |  |  |  |
| Voluntary |  | -0.955 (1.365) | -0.664 (1.226) |
| Lumpsum |  | 1.038 (1.014) | -1.552 (1.234) |
| Choice Experiment |  |  | -2.505\* (1.457) |
| Peer Review |  |  | 3.278\*\* (1.521) |
| Constant | 1.525 (1.371) | 10.921 (30.409) | -3.082 (25.732) |
| Number of Observations | 25 | 25 | 25 |
| Log Likelihood | -35.842 | -26.193 | -18.166 |
| Akaike Inf. Crit. | 81.683 | 76.386 | 68.332 |
| Log-likelihood Test | 10\*\* | 9.2\*\* | 6\* |
|  | | | |

\*\*\*,\*\*,\*denotes significance at 1%, 5% and 10%, respectively; WTP denotes willingness to pay.

**Table A7. Model 2 Meta-regression results (US Data)**

|  |  |  |  |
| --- | --- | --- | --- |
|  | | | |
|  | **Model 2: US Data** | | |
|  | **(Restricted)** |  | **(Restricted)** |
|  | | | |
| Dependent Variable: Log (WTP) - Log (Acreage Change) |  |  |  |
| **Context** |  |  |  |
| Log (Acreage) | -0.042 (0.120) | -0.084 (0.124) | 0.115 (0.106) |
| Log (Year) |  |  | -0.345\* (0.196) |
| Local |  |  | 3.176\*\*\* (0.801) |
| Provision |  | -1.486 (1.002) | -2.767\*\*\* (0.745) |
| Regulation |  | 0.969 (1.066) | 1.313 (0.884) |
| Cultural |  | -1.417 (1.202) | -0.737 (0.715) |
| Forest |  | 1.019\* (0.523) | 1.075\* (0.560) |
| Log(Income) |  | 2.514 (2.463) | 2.456 (1.647) |
| **Moderator** |  |  |  |
| Voluntary |  | -0.703 (1.321) | 0.331 (0.825) |
| Lumpsum |  | 1.725\* (0.947) | 0.129 (0.819) |
| Choice Experiment |  |  | 0.220 (0.938) |
| Peer Review |  |  | 1.606 (1.058) |
| Constant | -2.781\*\* (1.169) | -30.709 (28.033) | -33.264\* (18.678) |
| Number of Observations | 25 | 25 | 25 |
| Log Likelihood | -41.442 | -28.737 | -21.965 |
| Akaike Inf. Crit. | 90.884 | 79.473 | 73.930 |
| Log-likelihood Test | 18\*\*\* | 15\*\*\* | 0.9 |
|  | | | |

**Table A8. Adding up test**

|  |  |  |  |
| --- | --- | --- | --- |
| Scenario (acres, 1000s) | US-Canada Model Predicted WTP |  | US Model Predicted WTP |
|  |  | Forested, Local |  |
| 10 to 10.3 | 3.82 |  | 23.21 |
| 10.3 to 10.5 | 3.17 |  | 21.73 |
| 10 to 10.5 | 4.85 |  | 25.19 |
| Adding-up error (%) | 44.22 |  | 78.39 |
|  |  | Forested, Province |  |
| 10 to 10.3 | 0.49 |  | 3.66 |
| 10.3 to 10.5 | 0.40 |  | 3.43 |
| 10 to 10.5 | 0.62 |  | 3.97 |
| Adding-up error (%) | 44.22 |  | 78.39 |
|  |  | Non-forested, Local |  |
| 10 to 10.3 | 2.98 |  | 6.38 |
| 10.3 to 10.5 | 2.47 |  | 5.97 |
| 10 to 10.5 | 3.77 |  | 6.92 |
| Adding-up error (%) | 44.22 |  | 78.39 |
|  |  | Non-forested, Local |  |
| 10 to 10.3 | 0.70 |  | 0.50 |
| 10.3 to 10.5 | 0.58 |  | 0.46 |
| 10 to 10.5 | 0.88 |  | 0.54 |
| Adding-up error (%) | 44.22 |  | 78.39 |

1. https://www.evri.ca/en [↑](#footnote-ref-1)
2. [↑](#footnote-ref-2)
3. The estimated effect of a binary variable relative to the reference group is estimated using the exponent of the estimated coefficient of the variable minus 1. For instance, for binary variable local, it is exp (1.258) – 1 = 2.52. [↑](#footnote-ref-3)