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Willingness to Pay for Water Quality Improvements in the United States and Canada: Considering Possibilities for International Meta-Analysis and Benefit Transfer

Robert J. Johnston and Paul J. Thomassin

This paper presents a multinational meta-analysis estimated to identify systematic components of willingness to pay for surface water quality improvements, developed to support benefit transfer for Canadian policy development. Metadata are drawn from stated preference studies that estimate WTP for water quality changes affecting aquatic life habitats—a type of study with few Canadian examples. The goals of this paper are to assess the properties of a multinational (United States/Canada) meta-analysis compared to a single-country (U.S.) analog; illustrate the potential information that may be derived as well as the analytical challenges; and assess the performance of resulting meta-functions for benefit transfer.

Key Words: meta-regression analysis, stated preference, water quality, willingness to pay, benefit cost analysis

Policy analysts frequently rely on benefit function transfer (BFT) as a source of nonmarket welfare estimates, with benefit functions drawn from individual primary studies in the literature. The availability of applicable site-specific benefit functions, however, is limited, particularly those drawn from study sites of sufficient similarity to the policy sites in question. In cases for which a closely matching study site function is not available, a parameterized meta-analytic benefit function, estimated using a meta-regression model (MRM) of many primary study results, can provide the analyst with a viable alternative

(Bergstrom and Taylor 2006, Rosenberger and Loomis 2000). Results of prior MRMs have been promising with regard to the ability of such models to synthesize information regarding willingness to pay (WTP) and reveal systematic patterns unapparent from individual primary studies (Rosenberger and Johnston 2009).

BFT applications of meta-analysis (MA) typically involve the use of MRMs in which the dependent variable in a Bayesian or classical regression model is a summary welfare statistic (e.g., WTP estimate) drawn from comparable primary studies. Independent or moderator variables in the regression equation characterize corresponding attributes of the resource, policy, site, and affected population that are hypothesized to explain observed variation in the dependent variable across primary study observations (Nelson and Kennedy 2009). The estimated regression equation characterizes a value surface

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that reflects multidimensional patterns in estimated WTP across the empirical observations that comprise the metadata. The use of the estimated regression equation for BFT requires the analyst then to assign values (i.e., choose variable levels) for independent variables reflecting conditions or attributes at an unstudied policy site, so that a transferable WTP prediction can be obtained.

Much of the literature on BFT is derived from work in countries such as the United States with extensive valuation literatures. Other nations, however, have less extensive collections of non-market valuation studies. In such cases, options for within-country benefit transfer are limited, causing some to explore options for international benefit transfer (Ready et al. 2004, Ready and Navrud 2006). Options include standard site-to-site function transfers adjusted for exchange rates and other cross-border differences (Brouwer and Bateman 2005, Kristófersson and Navrud 2007, Ready et al. 2004, Ready and Navrud 2006), as well MRMs estimated with multiple country data (Brander, van Beukering, and Cesar 2007, Brouwer et al. 1999, Lindhjem and Navrud 2008, Santos 1998). Multinational MRMs may be particularly tempting in countries for which a relatively small number of primary studies are available, both reducing the likelihood of a good site match for site-to-site BFT and the number of in-country studies suitable for MA. In such cases, multinational metadata might combine in-country studies with out-of-country information to obtain sufficient degrees of freedom for MRMs. A potential benefit of MA in such cases is the ability to identify systematic value surface differences between nations, thereby promoting more informed WTP adjustments.

The potential allure of such approaches aside, the ability of MRMs to ameliorate the challenges of international benefit transfer remains unclear. Although the environmental economics literature includes a number of multinational MRMs, it provides only limited evidence regarding differences in WTP value surfaces across countries (Johnston and Rosenberger 2010). Moreover, with the exception of a few notable works, the literature offers modest guidance regarding difficulties involved in such analyses (Lindhjem and Navrud 2008, Ready and Navrud 2006), including the potential implications of pooling

metadata across countries. Despite increasing use of MRMs in environmental economics, reliable transfers are not assured (Bergstrom and Taylor 2006, Johnston and Rosenberger 2010, Moeltner, Boyle, and Patterson 2007, Nelson and Kennedy 2009, Smith and Pattanayak 2002); such challenges can be magnified when metadata pool observations across different countries.

Considering both the empirical possibilities and challenges, can multinational MRMs promote improved benefit transfers in countries with a less extensive valuation literature? The present article addresses this question for a case study involving proposed Canadian agricultural policies. Results are drawn from an MRM conducted to identify systematic components of WTP for surface water quality improvements across U.S. and Canadian observations and to isolate differences in value surfaces between the two countries. Metadata are drawn from stated preference valuation studies that estimate total (use and nonuse) WTP for water quality changes that affect aquatic life habitats or recreational uses—a type of primary study with few Canadian examples. The goals of the paper are to (1) assess the properties of a multinational (U.S. and Canadian) MRM compared to a single-country (U.S.) analog; (2) illustrate the potential information that may be derived as well as the analytical challenges; and (3) assess the relative performance of related BFTs.

International Meta-Analysis

When conducting benefit transfers across national borders, one must account for a variety of complications not encountered in intra-country transfer. For example, it may be necessary to adjust for WTP patterns related to such factors as (1) currency conversion, (2) user or population attributes, (3) wealth versus income, (4) cultural differences, (5) the extent of the market, and (6) value adjustments (Ready et al. 2004, Ready and Navrud 2006). In some cases, steps required to reconcile variables across borders are similar for all transfer methods (e.g., currency conversion), or are identical to those facing purely domestic transfers (e.g., determining the extent of the market). In other cases, MA might provide a means to ameliorate or reveal potential complications that affect other transfer methods

(Rosenberger and Johnston 2009). For example, an appropriately specified international MRM might reveal systematic differences in value surfaces across different countries and thereby promote more appropriate BFTs.

Analysts considering the development of meta-data from multiple countries, however, face nontrivial challenges related to study heterogeneity and sample selection considerations across nations (Lindhjem and Navrud 2008, Rosenberger and Johnston 2009). For example, the heterogeneity of study attributes across countries may be greater than that of the same attributes within countries (Lindhjem and Navrud 2008, Ready and Navrud 2006). This can lead to questions regarding the appropriateness of data pooling (Lindhjem and Navrud 2008). In addition, sample selection patterns may vary across countries. For example, some countries such as the United States have accumulated a wide and varied literature of non-market valuation. Many other countries, however, do not have such a rich nonmarket valuation literature. This can lead to concerns regarding potential research selection bias (Rosenberger and Johnston 2009), as well as the broader interpretability of metadata dominated by observations from a single country.

These and related issues have yet to be addressed comprehensively by the benefit transfer literature. While the valuation literature includes a number of multinational MRMs (e.g., Brander, Florax, and Vermaat 2006, Brander, van Beukering, and Cesar 2007, Brouwer et al. 1999, Santos 1998 and 2007, Lindhjem and Navrud 2008), the authors are aware of only one article that offers in-depth discussion of the complexities involved with multinational MA and related benefit transfers for environmental goods (Lindhjem and Navrud 2008). Multinational meta-analyses often give scant attention to the empirical challenges associated with multinational data, and many MRMs combine data from three or more nations, potentially compounding these already significant challenges. In few cases are multinational MRMs compared to otherwise similar single-nation MRMs, such that potential implications of multinational data pooling may be explored. Moreover, and perhaps most importantly, existing works provide limited evidence to help analysts determine whether

multinational MRMs can offer a viable alternative for benefit transfer. The few assessments that have been conducted suggest the potential for large transfer errors (e.g., Brander, van Beukering, and Cesar 2007, Lindhjem and Navrud 2008).

The present analysis addresses such issues for a more restricted and perhaps viable class of multinational MRM based on metadata from two similar and neighboring countries, the United States and Canada. The analysis is designed to allow direct comparisons to a parallel U.S. MRM, as well as a prior U.S.-only MRM drawn from similar metadata (Johnston et al. 2005). The contrast of parallel single and multiple country MRMs provides insight into the robustness of results to multinational data pooling. The contrast also illustrates challenges involved in the estimation and interpretation of a multinational MRM across even similar countries.

Data and Conceptual Approach

The policy context for the present work involved BFT for Agriculture and Agri-Food Canada (AAFC) proposals to reduce agriculture-related movement of sediments, nutrients, pathogens, pesticides, and salts into Canadian surface waters. Although policymakers originally expressed a desire for an MRM derived from Canadian data alone, such a model was infeasible because of the lack of sufficient Canadian studies. For this reason, the present metadata combine U.S. and Canadian observations, providing at least a potential means to estimate a benefit meta-function that incorporates greater information than one based solely on Canadian data.

The metadata are drawn from U.S. and Canadian stated preference studies that estimate total (use and nonuse) WTP for water quality changes that affect aquatic life habitats or recreational uses. Specifically, we extend the metadata of Johnston et al. (2005) with a set of comparable Canadian observations to estimate a joint Canadian-U.S. value surface. Criteria for study inclusion were: (1) a requirement that the study estimate total per household WTP; (2) a requirement that the water quality change being valued affected aquatic life and/or habitat in a water body that provides recreational use; (3) a requirement that the study was conducted in the United

States or Canada; (4) a requirement that the study apply stated preference methods accepted by the nonmarket valuation literature; and (5) a requirement that the study provide sufficient information regarding resource, site, and study attributes to warrant inclusion in the metadata.

The resulting metadata include ninety-seven observations from thirty-six unique studies published between 1981 and 2003. Of these, sixteen observations are derived from Canadian studies, representing 17 percent of the total metadata. The studies include nineteen journal articles, ten research reports,¹ four Ph.D. dissertations, one book, one book chapter, and one master's thesis. The number of observations exceeds the number of studies because many studies provide more than one WTP estimate. Multiple estimates are often available due to in-study variations in such factors as the extent of amenity change, elicitation methods, water body type, recreational activities affected, and species affected. Stated preference methods represented in the metadata include both open-ended contingent valuation and choice-based survey methods. Table 1 summarizes characteristics for included studies.

Canadian observations in the metadata are drawn from two studies (Brox Kumar, and Stollery 1996, Dupont 2003); despite the extensive review summarized above no other Canadian studies could be found that met all inclusion criteria. Brox, Kumar, and Stollery (1996) provide various estimates of WTP for water quality improvements in the Grand River watershed in Ontario, only one of which met all inclusion criteria. Dupont (2003) estimates WTP for water quality improvements that support different types of aquatic life and recreational activities in nearby Hamilton Harbor, also in Ontario; this study provides the majority of Canadian observations in the metadata. Both studies are associated with western Lake Ontario waters or watersheds in relatively urbanized areas, and both address waters with significant recreational use. Hence, MRM results must be interpreted not only with respect to the number of Canadian observations in the

metadata, but also with regard to the geographic range and characteristics of the Canadian waters that are represented.

Based on theory and past findings, we expect that various attributes may be associated with value surfaces for surface water quality improvements (Johnston, Besedin, and Wardwell 2003, Johnston et al. 2005, Van Houtven, Powers, and Pattanayak 2007). These include attributes characterizing study and methodology, surveyed populations, geographic region, water body type, and resource condition and change. *Study and methodology* attributes characterize such features as the year in which a study was conducted, payment vehicle and elicitation format, WTP estimation methods, and response rates. *Surveyed populations* attributes characterize such features as average income and the representation of users and nonusers within the survey sample. *Geographic region* attributes characterize the geographic region in which the study was conducted. *Water body type* attributes characterize hydrological characteristics of the affected water bodies. Finally, *resource condition and change* attributes characterize baseline conditions, resource uses, and the extent of water quality change. Table 2 summarizes the set of independent variables included in the MA.

Interpreting and Reconciling Model Variables

A critical component of any MA is the reconciliation of variables across observations (Johnston et al. 2005, Smith and Pattanayak 2002, Smith, Van Houtven, and Pattanayak 2002). To allow meaningful comparisons with the parallel single-country MRM of Johnston et al. (2005), we follow this earlier study in variable reconciliations.² Among the reconciled variables most central to the model are those characterizing water quality. Many (twenty-six) observations in the metadata characterize quality changes using variants of the Resources For the Future (RFF) water quality ladder (McClelland 1974, Mitchell and Carson 1989, p. 342, Vaughan 1986). This scale is linked to specific pollutant levels that, in turn, are linked to the presence of aquatic species

¹ In some cases, peer-reviewed journal articles failed to provide sufficient information on study attributes, necessitating a review of more detailed technical reports (from which the journal articles were derived). In such cases, associated technical reports were referenced as the primary data source.

² See Van Houtven, Powers, and Pattanayak (2007) for an alternative means of reconciling water quality measures.

and suitability for particular recreational uses. The ladder also allows the use of objective water quality parameters (e.g., dissolved oxygen) to characterize ecosystem services or uses provided by a given water body (Johnston and Besedin 2009, Vaughan 1986).

Other observations in the metadata rely on alternative scales or indicators (e.g., ordinal rankings, often paired with verbal descriptions) to measure water quality. For studies that do not include the water quality ladder as an original study element, the descriptions of water quality that were included—either using descriptive (e.g., suitable for swimming) or objective criteria—are used to map water quality measures to the RFF ladder following methods detailed by Johnston et al. (2005) and Johnston and Besedin (2009). For studies in which such information was not provided, we use descriptive information available from studies (e.g., amount/indication of the presence of specific pollutants; historical decline of the quality of the resource) to approximate the baseline level of water quality and the magnitude of the change. To account for the possibility of systematic biases involved in mapping descriptive water quality measures to the RFF ladder, the binary variable *wq_ladder* is defined. This variable identifies studies in which water quality ladder measurements were an original component of the survey instrument.

The metadata and associated MRMs also allow the estimated partial slope associated with water quality changes to vary as a function of the primary affected species group. Following Johnston et al. (2005), we include the water quality variable (see above) in the model as a set of interactions with dummy variables characterizing the primary species affected by water quality change, as noted in the original studies. These interaction variables distinguish the effects of water quality change for fish (*WQ_fish*); shellfish (*WQ_shell*); multiple species (*WQ_many*); and non-specified species (*WQ_non*).

All monetary values are converted to 2002 U.S. dollar equivalents. For U.S. observations, this required transformation using the U.S. Bureau of Labor Statistics nonseasonally adjusted average Consumer Price Index (CPI) for all urban consumers. For Canadian observations, parallel adjustments were made using Statistics Canada

Consumer Price Index (2007). Canadian observations were then adjusted to U.S. dollar equivalents using the average annual G.5 exchange rates published by the Board of Governors of the Federal Reserve System (U.S.). These adjustments ensure that monetary amounts are comparable across observations. Additional discussions of currency conversion in benefit transfer are provided by Ready and Navrud (2006) and Lindhjem and Navrud (2008).

The Empirical Model

Two parallel models are estimated: one with joint U.S. and Canadian metadata (the U.S./Canada model) and one with U.S.-only metadata (the U.S. model). Following standard approaches, MRMs are estimated using multilevel (or random-effects) models to address potential correlation among observations gathered from single studies as well as robust variance estimation to account for potential heteroskedasticity (Nelson and Kennedy 2009). All observations are drawn from stated preference analyses that estimate comparable Hicksian welfare measures, following guidance to avoid metadata that combine theoretically distinct measures (Nelson and Kennedy 2009, Smith and Pattanayak 2002).

The dependent variable is the natural log of estimated household WTP for water quality improvements in aquatic habitat. All right-hand-side variables are linear, resulting in a semi-log functional form. This functional form follows Johnston et al. (2005) and was chosen based on its statistical performance, ability to capture curvature in the valuation function, and because it allows independent variables to influence WTP in a multiplicative rather than additive manner. Preliminary models find similar results from weighted and unweighted models; unweighted regression results are shown here following Bateman and Jones (2003).³

Degrees of freedom limitations related to the small number of Canadian observations prevent estimation of a model including a comprehensive set of systematically varying slopes between U.S. and Canadian observations. Preliminary models

³ However, see counter arguments of Poe, Boyle, and Bergstrom (2001).

Table 1. Characteristics of Studies Included in Meta-Analysis

Citation for Study	No. of Obs. in Metadata	State or Region	Water Body Type	Species Affected	Methodology	Adjusted WTP Values ^a
Aiken (1985)	1	CO	all freshwater	game fish	contingent valuation (CV)—multiple methods ^b	\$167.98
Anderson and Edwards (1986)	1	RI	salt pond/marshes	unspecified	contingent valuation (CV)—open ended	\$157.14
Azevedo, Herriges, and Kling (2001)	5	IA	lake	game fish	CV—discrete choice	\$17.76 - \$118.68
Bockstael, McConnell, and Strand (1989)	2	MD	estuary	unspecified	CV—discrete choice	\$65.80 - \$209.51
Brox, Kumar, and Stollery (1996)	1	Ontario (Canada)	all freshwater	unspecified	CV—payment card	\$15.07
Cameron and Huppert (1989)	1	CA	river/stream	game fish	CV—discrete choice	\$43.07
Carson et al. (1994)	2	CA	estuary	game fish; multiple categories	CV—discrete choice	\$35.83 - \$67.47
Clonts and Malone (1990)	3	AL	river/stream	unspecified	CV—iterative bidding	\$68.10 - \$110.85
Croke, Fabian, and Brenniman (1987)	9	IL	river/stream	all recreational fish; none	CV—iterative bidding	\$53.31 - \$81.46
Cronin (1982)	4	DC	river/stream	all recreational fish	CV—open ended	\$61.85 - \$212.73
Desvousges, Smith, and McGivney (1983)	2	PA	river/stream	unspecified	CV—discrete choice	\$111.41 - \$220.24
De Zoysa (1995)	2	OH	lake; river and lake	multiple categories	CV—discrete choice	\$35.88 - \$61.02
Dupont (2003)	15	Ontario (Canada)	single lake	unspecified; fish	CV—discrete choice	\$6.60 - \$61.24 ^c
Farber and Griner (2000)	3	PA	river/stream	all recreational fish	CV—discrete choice	\$44.22 - \$105.58
Hayes, Tyrrell, and Anderson (1992)	2	RI	estuary	shellfish; none	CV—discrete choice	\$339.72 - \$351.47
Herriges and Shogren (1996)	2	IA	lake	all recreational fish	CV—discrete choice	\$53.66 - \$180.35
Huang, Haab, and Whitehead (1997)	2	NC	estuary	multiple categories	CV—discrete choice; revealed and stated preference	\$221.75 - \$228.07

Table 1. *Continued*

Lant and Roberts (1990)	3	IA/IL	river/stream	game fish; all recreational fish	CV—discrete choice	\$107.86 - \$134.18
Loomis (1996)	1	WA	river/stream	game fish	CV—discrete choice	\$80.93
Lyke (1993)	2	WI	lake	game fish	CV—discrete choice	\$51.96 - \$84.99
Magat et al. (2000)	2	CO/NC	all freshwater	all aquatic species	CV—iterative bidding	\$114.49 - \$376.61
Mathews, Homans, and Easter (1999)	2	MN	river/stream	all aquatic species	CV—discrete choice	\$15.77 - \$22.01
Mitchell and Carson (1981)	1	National	all freshwater	all aquatic species	CV—discrete choice	\$242.34
Olsen, Richards, and Scott (1991)	3	Pacific NW	river/stream	game fish	CV—open ended	\$34.48 - \$107.59
Roberts and Leitch (1997)	1	MN/SD	lake	multiple categories	CV—discrete choice	\$7.26
Rowe et al. (1985)	1	CO	river/stream	game fish	CV—open ended	\$117.04
Sanders, Walsh, and Loomis (1990)	4	CO	river/stream	unspecified	CV—open ended	\$70.44 - \$171.59
Schulze et al. (1995)	2	MT	river and lake	multiple categories	CV—discrete choice	\$15.08 - \$21.16
Stumborg, Baerenklau, and Bishop (2001)	2	WI	lake	multiple categories	CV—discrete choice	\$57.90 - \$88.38
Sutherland and Walsh (1985)	1	MT	river and lake	unspecified	CV—open ended	\$126.98
Welle (1986)	6	MN	all freshwater	multiple categories; game fish	multiple methods	\$95.30 - \$207.32
Wey (1990)	2	RI	salt pond/marshes	shellfish	multiple methods	\$55.61 - \$200.50
Whitehead and Groothuis (1992)	3	NC	river/stream	all recreational fish	CV—open ended	\$27.74 - \$46.23
Whitehead et al. (1995)	2	NC	estuary	multiple categories	CV—iterative bidding	\$68.08 - \$97.91
Whittington et al. (1994)	1	TX	estuary	all aquatic species	CV—discrete choice	\$169.32

^a As noted in the text, reported WTP values apply to different levels of water quality change. All WTP estimates are converted to 2002 U.S. dollars and rounded to the nearest cent, and hence may not match exactly the raw WTP estimates reported in source studies. Where multiple WTP estimates are available from a given study, the range of values is presented.

^b The author averaged WTP estimates derived from both open-ended and iterative bidding methods to obtain a single reported WTP estimate.

^c WTP estimates for nested policy options were summed in some cases to obtain total WTP estimates for combined policies.

Table 2. Meta-Analysis Variables and Descriptive Statistics

Variable	Description	Units/Measurement	Mean (Std. Dev.)
<i>ln_WTP</i>	Natural log of willingness to pay for specified resource improvements, converted to 2002 U.S. dollars.	Natural log of dollars (Range: 1.98 to 5.93)	4.21 (0.91)
<i>year_indx</i>	Year in which the study was conducted, converted to an index by subtracting 1970.	Year Index (Range: 3 to 31)	19.80 (6.42)
<i>discrete_ch</i>	Binary variable indicating that WTP was estimated using a discrete choice survey instrument.	Binary (Range: 0 or 1)	0.44 (0.50)
<i>voluntary</i>	Binary variable indicating that WTP was estimated using a payment vehicle described as voluntary.	Binary (Range: 0 or 1)	0.06 (0.24)
<i>interview</i>	Binary variable indicating that the survey was conducted using in-person interviews (default is a telephone survey).	Binary (Range: 0 or 1)	0.15 (0.36)
<i>mail</i>	Binary variable indicating that the survey was conducted through the mail.	Binary (Range: 0 or 1)	0.63 (0.49)
<i>lump_sum</i>	Binary variable indicating that payments were to occur on something other than a long-term annual basis (e.g., a single lump sum payment).	Binary (Range: 0 or 1)	0.33 (0.47)
<i>wq_change</i>	Change in mean water quality, specified on the RFF water quality ladder. Defined as the difference between baseline and post-improvement quality. Where the original study (survey) did not use the RFF water quality ladder, we mapped water quality descriptions to analogous levels on the RFF ladder to derive water quality change (see text). <i>Note:</i> This variable only included in model as part of an interaction term (<i>WQ_fish</i> , <i>WQ_shell</i> , <i>WQ_muny</i> , <i>WQ_non</i>).	Water quality ladder units (Range: 0.5 to 5.75)	See individual WQ variables below
<i>wq_ladder</i>	Binary variable indicating that the original survey reported resource changes using the Resources for the Future water quality ladder.	Binary (Range: 0 or 1)	0.27 (0.45)
<i>protest_bids</i>	Binary variable indicating that protest bids were excluded when estimating WTP.	Binary (Range: 0 or 1)	0.38 (0.49)
<i>outlier_bids</i>	Binary variable indicating that outlier bids were excluded when estimating WTP.	Binary (Range: 0 or 1)	0.19 (0.39)
<i>hi_response</i>	Binary variable indicating that the survey response rate exceeded 74% (i.e., 75% or above).	Binary (Range: 0 or 1)	0.26 (0.44)
<i>income</i>	Mean income of survey respondents, either as reported by the original survey or calculated based on census averages for the original surveyed region.	Dollars (Range: 30396 to 137693)	44956.14 (12590.26)
<i>nonusers</i>	Binary variable indicating that the survey was implemented over a population of nonusers (default category for this dummy is a survey of any population including users).	Binary (Range: 0 or 1)	0.21 (0.41)
<i>estuary_bay</i>	Binary variable indicating that resource change explicitly takes place in an estuary or large bay (default is a change in a river).	Binary (Range: 0 or 1)	0.12 (0.33)

Table 2. Continued

<i>lake</i>	Binary variable indicating that resource change explicitly takes place in a single lake.	Binary (Range: 0 or 1)	0.26	(0.44)
<i>salt_pond</i>	Binary variable indicating that resource change explicitly takes place in multiple salt ponds.	Binary (Range: 0 or 1)	0.04	(0.20)
<i>regional_fresh</i>	Binary variable indicating that resource change explicitly takes place in multiple fresh water bodies in an identified geographical region.	Binary (Range: 0 or 1)	0.31	(0.46)
<i>southeast</i>	Binary variable indicating that survey was conducted in the USDA Southeast region (default is Northeast region).	Binary (Range: 0 or 1)	0.10	(0.31)
<i>pacif_moun</i>	Binary variable indicating that survey was conducted in the USDA Pacific/Mountain region.	Binary (Range: 0 or 1)	0.17	(0.37)
<i>plains</i>	Binary variable indicating that survey was conducted in the USDA Northern or Southern Plains region.	Binary (Range: 0 or 1)	0.02	(0.14)
<i>mult_reg</i>	Binary variable indicating that survey included respondents from more than one of the regions.	Binary (Range: 0 or 1)	0.03	(0.17)
<i>Canada</i>	Binary variable indicating that survey was conducted in Canada.	Binary (Range: 0 or 1)	0.17	(0.37)
<i>WQ_fish</i>	Interaction variable: <i>wq_change</i> multiplied by a binary variable identifying studies in which water quality improvements are stated to benefit primarily fin fish. Default is zero (i.e., change did not affect fish).	Water quality ladder units (Range: 0.5 to 5.75)	1.13	(1.47)
<i>WQ_shell</i>	Interaction variable: <i>wq_change</i> multiplied by a binary variable identifying studies in which water quality improvements are stated to benefit primarily shellfish. Default is zero (i.e., change did not affect shellfish).	Water quality ladder units (Range: 0.5 to 4.00)	0.10	(0.58)
<i>WQ_many</i>	Interaction variable: <i>wq_change</i> multiplied by a binary variable identifying studies in which water quality improvements are stated to benefit multiple species types. Default is zero (i.e., change did not affect multiple species).	Water quality ladder units (Range: 0.5 to 4.00)	0.53	(1.12)
<i>WQ_non</i>	Interaction variable: <i>wq_change</i> multiplied by a binary variable identifying studies in which species benefiting from water quality improvements remain unspecified. Default is zero (i.e., change did not affect unspecified species).	Water quality ladder units (Range: 0.5 to 2.5)	0.53	(0.93)
<i>fishplus</i>	Binary variable identifying studies in which a substantial fish population or harvest change is reported in the survey (e.g., >50% increase).	Binary (Range: 0 or 1)	0.20	(0.40)
<i>baseline</i>	Baseline water quality, specified on the RFF water quality ladder.	Water quality ladder units (Range: 0 to 7)	4.61	(2.27)
<i>baseline_Canada</i>	Interaction variable: <i>baseline</i> multiplied by <i>Canada</i> .	Water quality ladder units (Range: 0 to 7)	0.76	(1.76)

were instead used to arrive at a final specification that includes two moderator variables distinguishing Canadian observations, *Canada* and *Canada_baseline* (Table 2). The former is a binary (dummy) variable identifying Canadian observations; the second is a multiplicative interaction between *Canada* and a variable quantifying baseline water quality (*baseline*). Additional details are provided below.

Model Results

Results are presented in Table 3. Likelihood ratio tests indicate that model variables are jointly significant at $p < 0.0001$ for both the U.S./Canada and U.S. models ($-2 \log \text{likelihood } \chi^2 = 121.2$ and 92.9 , respectively). Of 29 parameter estimates in the U.S./Canada model, 25 are statistically significant at $p < 0.10$, with the majority statistically significant at $p < 0.01$; 24 out of 27 parameter estimates are statistically significant in the U.S. model. Random-effects associated with systematic study-level variance (σ_u^2), however, are not statistically significant; σ_u^2 converges to a near-zero value in both models. Statistical properties of the estimated MRMs compare favorably to prior meta-analyses in the literature (see Nelson and Kennedy 2009) and suggest similar overall performance to the original U.S.-only model of Johnston et al. (2005).

Estimation results are similar for the U.S. and U.S./Canada MRMs, and in nearly all cases match those expected based on theory, intuition, and prior findings in the literature. Because of this, the following discussion suppresses description of value surfaces and instead emphasizes differences between U.S. and Canadian results and implications for BFT. Those interested in a broader description of value surfaces for water quality improvements are referred to Johnston et al. (2005), Johnston and Besedin (2009), and Van Houtven, Powers, and Pattanayak (2007).

Contrasting U.S. and Canadian Value Surfaces

Results show a high degree of robustness between the U.S./Canada and U.S. models. Among variables shared across both models, both statistical significance and magnitudes are similar. Although these results should be interpreted in light of the relatively small number of observations from

Canadian studies, such findings appear promising for commensurability of value surfaces across Canadian and U.S. metadata. That is, most results are robust to the addition of Canadian observations to the metadata. These results aside, results also point to statistically significant and large magnitude divergences between Canadian and U.S. WTP. The parameter estimate for the binary variable *Canada* is of large magnitude and statistically significant at $p < 0.0001$. This result is robust across all preliminary models, in addition to the final model illustrated here. Although based on a relatively small number of Canadian observations (sixteen) and studies (two), this finding suggests that for otherwise identical water quality changes and policy contexts, Canadian WTP is significantly smaller than U.S. WTP, even after one adjusts for exchange rates and other differences between the two countries.

The rationale for this finding is unclear, but might be related to such factors as variations in substitutes and complements across U.S. and Canadian observations, a systematic difference in preferences between U.S. and Canadian respondents, or perhaps other unobserved factors characteristic of the geographic region within which both Canadian studies were conducted. Without additional data, these and other possible explanations can only be considered speculations. A related question concerns potential relationships—if any—between the lower estimated values from Canadian studies and the small number of Canadian studies that have been conducted, following research selection themes elucidated by Rosenberger and Johnston (2009). The existence of such relationships, however, is also speculative. The paucity of Canadian studies might be due to any number of other factors, including broader cultural and/or political attitudes towards the use of nonmarket valuation for policy guidance, among many other possibilities.

To further explore the rationale for lower WTP among Canadian observations and linkages to baseline water quality, we also include in the model the interaction variable *baseline_Canada*. Estimation results for this variable are statistically significant but counterintuitive in sign (the only counterintuitive, statistically significant result found in the model). Specifically, when one combines findings for *baseline* and *baseline_*

Table 3. Meta-Regression Results (semi-log, random-effects model; White corrected standard errors)

Moderator	Canada/U.S. Model		U.S. Model	
	Coefficient	Pr > t	Coefficient	Pr > t
<i>intercept</i>	5.6916	0.0001	5.5760	0.0001
<i>year_indx</i>	-0.1199	0.0001	-0.1259	0.0001
<i>discrete_ch</i>	0.914	0.0001	0.9793	0.0001
<i>voluntary</i>	-0.8621	0.0024	-1.1338	0.0001
<i>income</i>	-0.0000012	0.8008	0.0000022	0.6071
<i>wq_ladder</i>	-0.2557	0.2499	-0.2340	0.2534
<i>protest_bids</i>	0.9282	0.0001	0.9701	0.0001
<i>outlier_bids</i>	-0.6459	0.0001	-0.7129	0.0001
<i>hi_response</i>	-0.9348	0.0001	-0.9565	0.0001
<i>lake</i>	0.7220	0.0069	0.8279	0.0005
<i>estuary_bay</i>	0.2248	0.1903	0.2377	0.1582
<i>salt_pond</i>	0.9361	0.0007	1.0027	0.0007
<i>regional_fresh</i>	0.3034	0.0203	0.3735	0.0010
<i>southeast</i>	1.0504	0.0004	1.2393	0.0001
<i>plains</i>	-0.8693	0.0022	-0.9809	0.0001
<i>pacif_mount</i>	-0.3415	0.0133	-0.3570	0.0089
<i>mult_reg</i>	0.5502	0.0105	0.4967	0.0224
<i>Canada</i>	-5.6777	0.0001	-	-
<i>nonusers</i>	-0.6084	0.0001	-0.5256	0.0001
<i>WQ_fish</i>	0.1989	0.0001	0.1598	0.0016
<i>WQ_shell</i>	0.2924	0.0001	0.2501	0.0006
<i>WQ_many</i>	0.2259	0.0013	0.1814	0.0111
<i>WQ_non</i>	0.3439	0.0001	0.3093	0.0010
<i>fishplus</i>	0.6477	0.0003	0.8745	0.0001
<i>baseline</i>	-0.1085	0.0189	-0.1219	0.0072
<i>baseline_Canada</i>	0.7759	0.0001	-	-
<i>interview</i>	1.1594	0.0001	1.3079	0.0001
<i>mail</i>	0.3019	0.1759	0.4733	0.0240
<i>lump_sum</i>	0.5716	0.0021	0.5440	0.0011
-2 Log Likelihood χ^2	121.2	0.0001	92.9	0.0001
Covariance Factors				
Study Level (σ_u^2)	<0.0001		<0.0001	
Residual (σ_e^2)	0.1480		0.1472	
Observations (N)	97		81	

Canada, results imply that Canadians are willing to pay greater amounts for quality improvements in water bodies that begin at higher baseline quality levels. There are a variety of possible explanations for this result. For example, Canadians might view improvements in higher-quality water bodies as more cost-effective in terms of the level of activities provided. Again, these results and any potential explanations must be considered in both light of the small number of observations from Canadian studies and the policy contexts within which these studies were conducted. Such explanations aside, results such as this point to the possibility of large and perhaps unanticipated value surface divergences between even neighboring and similar countries.

Benefit Transfer Applications and Assessments

Regardless of the reason for the illustrated differences between U.S. and Canadian value surfaces, these findings suggest that researchers should exercise extreme caution when conducting unadjusted BFT between the two countries—as results here show systematic differences in WTP that, if not corrected using MA or other means, could result in significant generalization error. For example, consider a scenario characterized by a one-unit improvement in WQ_{fish} ($WQ_{fish} = 1$) that occurs in a Canadian lake ($Canada = lake = 1$). Baseline water quality is assumed to be 5.0 on the 10-point water quality scale ($baseline = 5.0$). The gain in fish populations is not expected to be substantial ($fishplus = 0$). Values are assumed to reflect a combination of users and nonusers ($nonusers = 0$), and income is assumed to be at the mean level for Canadian observations ($income = 34,436$). Following Stapler and Johnston (2009), methodological variables are set at mean values for Canadian observations.

Based on the hypothetical scenario outlined above, the combined U.S./Canada model predicts a WTP value of \$31.83 CDN (\$20.27 U.S.), representing 2002 per-household WTP for a one-unit increase in WQ_{fish} , in Canada, tailored to the specific policy context characterized above. In contrast, if identical policy, site, and methodological assumptions are applied to a U.S. policy (i.e., all variables are held at identical levels

except $Canada = baseline_Canada = 0$), WTP increases to \$192.25 CDN (\$122.40 U.S.)—an increase of approximately 524 percent. Such results demonstrate the substantial predicted difference between U.S. and Canadian WTP for otherwise identical policy changes. While such results must be interpreted within the context of the current sample, they nonetheless suggest that single-study BFTs between U.S. and Canadian regions could risk substantial transfer errors.

Notwithstanding the various challenges in MRM benefit transfer, MA provides one of the only systematic means to adjust for such differences and perhaps ameliorate associated errors. Of particular interest in the current case is the ability of MRMs such as this one to promote more accurate transfers in countries with a smaller base of nonmarket valuation studies (e.g., Canada in the present case study). To characterize the benefit transfer potential of the current MRM for Canadian applications, Table 4 illustrates the results of a convergent validity benefit transfer assessment for all in-sample Canadian observations.

The assessment follows an in-sample convergent validity framework. We use the U.S./Canada MRM benefit function to forecast WTP for all Canadian observations in the sample; these transferred values are then compared to the original WTP estimates generated by the primary study observation in question. Selection of variable values for this convergent validity test follows standard approaches described by Stapler and Johnston (2009), Shrestha and Loomis (2003), Johnston and Besedin (2009), and others. To promote a realistic assessment of benefit transfer accuracy, we assume mean Canadian sample values for income and all methodological variables. Policy variables are assumed observable for each policy site, and are hence matched to those of each Canadian observation. Resulting meta-function benefit transfer estimates (in 2002 \$U.S.) are provided in the first column of Table 4, for each of the sixteen Canadian observations in the sample. These transfer estimates are compared to primary study values for each observation (Table 4, column 2), with associated absolute value percentage errors (column 3) calculated for each observation (cf. Rosenberger and Loomis 2000, Rosenberger and Stanley 2006).

Table 4. Transfer Accuracy for Canadian Observations: In-Sample U.S./Canada Meta-Function versus Unit Value Transfer

Canadian Obs.	Predicted WTP: Meta-function Transfer (2002 \$U.S.)	Primary Study WTP (2002 \$U.S.)	Absolute Value % Error (Meta-function Transfer)	Mean of Canadian Primary Study WTP (2002 \$U.S.)	Absolute Value % Error (Mean Unit Value Transfer)	Scenario ^a
1	\$28.12	\$41.86	32.81%	\$25.73	38.53%	$WQ_non = 2.5, baseline = 4.5, lake=1$
2	\$28.12	\$23.30	20.68%	\$25.73	10.42%	$WQ_non = 2.5, baseline = 4.5, lake=1$
3	\$15.30	\$13.88	10.27%	\$25.73	85.39%	$WQ_non = 2.5, baseline = 4.5, lake=1, nonusers=1$
4	\$25.13	\$11.20	124.41%	\$25.73	129.81%	$WQ_fish = 0.5, baseline = 4.5, lake=1, fishplus=1$
5	\$25.13	\$21.98	14.32%	\$25.73	17.07%	$WQ_non = 0.5, baseline = 4.5, lake=1, fishplus=1$
6	\$13.67	\$6.60	107.14%	\$25.73	289.76%	$WQ_non = 0.5, baseline = 4.5, lake=1, fishplus=1, nonusers=1$
7	\$37.40	\$61.24	38.92%	\$25.73	57.98%	$WQ_fish = 2.5, baseline = 4.5, lake=1, fishplus=1$
8	\$37.40	\$40.18	6.92%	\$25.73	35.97%	$WQ_non = 2.5, baseline = 4.5, lake=1, fishplus=1$
9	\$20.36	\$19.96	1.99%	\$25.73	28.93%	$WQ_non = 2.5, baseline = 4.5, lake=1, fishplus=1, nonusers=1$
10	\$37.40	\$41.91	10.75%	\$25.73	38.60%	$WQ_fish = 2.5, baseline = 4.5, lake=1, fishplus=1$
11	\$37.40	\$46.90	20.24%	\$25.73	45.13%	$WQ_non = 2.5, baseline = 4.5, lake=1, fishplus=1$
12	\$20.36	\$21.56	5.58%	\$25.73	19.36%	$WQ_non = 2.5, baseline = 4.5, lake=1, fishplus=1, nonusers=1$
13	\$12.97	\$24.09	46.15%	\$25.73	6.82%	$WQ_non = 0.25, baseline = 4.5, lake=1$
14	\$12.97	\$14.29	9.20%	\$25.73	80.10%	$WQ_non = 0.25, baseline = 4.5, lake=1$
15	\$7.06	\$7.69	8.23%	\$25.73	234.50%	$WQ_non = 0.25, baseline = 4.5, lake=1, nonusers=1$
16	\$58.33	\$15.07	287.07%	\$25.73	70.74%	$WQ_non = 1, baseline = 7, regional_fresh=1$
Mean % Error (Absolute Value)			46.54%		74.32%	

^a Scenarios characterized by *Canada* = 1 and Canadian mean values for methodological variables and income. Other variables are set to zero unless otherwise noted.

To place these convergent validity results in context, we also illustrate the parallel performance of mean unit-value transfers, in which the mean value of WTP (2002 \$U.S.) over all Canadian observations (\$25.73) is used as an alternative transfer value for each observation (Lindhjem and Navrud 2008). Such mean value unit transfers might be applied in countries for which a closely matching study site function is not available, and in the absence of a good site match analysts transfer a mean WTP over all available in-country studies.

Results (Table 4) suggest reasonable performance of meta-function transfer, with an average absolute value error over all Canadian observations of 46.54 percent, and individual errors ranging from 1.99 percent to 287.07 percent. This compares to a mean 74.32 percent absolute value error from mean unit value transfers. Such values compare favorably to typical generalization errors in the benefit transfer literature (Rosenberger and Stanley 2006) and those found in prior multinational MRMs, and suggest the potential feasibility of U.S./Canadian MRMs as a means to promote BFT accuracy for policy contexts in which few Canadian studies are available. Here, such methods outperform mean unit value transfers, and allow analysts to adjust not only for attributes of the policy context but also for potential differences in value surfaces between the United States and Canada.

The use of U.S.-only MRM results to conduct meta-function benefit transfers for Canadian observations provides less satisfactory results. Table 5 illustrates a parallel convergent validity test in which the *U.S.-only* MRM is used to forecast out-of-sample values for each *Canadian* observation in the full Canada/U.S. metadata. Other than this difference, methods and variable assignments for the assessment mirror those in Table 4 above. In contrast to the low-to-moderate generalization errors found in the Canada/U.S. meta-function transfer (Table 4), errors shown in Table 5 (using U.S.-only MRM results to forecast Canadian WTP) would likely render transfers unsuitable for applied use, with an average absolute value error exceeding 1,059 percent. Combined results from Tables 4 and 5 illustrate the potential benefits of pooling U.S. and Canadian data to generate a multinational MA

as a means to approximate Canadian WTP values, compared to the use of an MA estimated solely from U.S. observations. They also suggest the hazards of using a single-country MRM (here, the U.S. model) to conduct BFT to another country.

Conclusions

Results of the present analysis are promising for at least the prospect of obtaining inferences regarding value surfaces and benefit transfer possibilities from multiple country metadata that supplement observations from a relatively data-poor country with those from a data-rich country. Results here show favorable and robust statistical properties of the U.S./Canada MRM compared to the U.S.-only model. Results also suggest systematic differences between Canadian and U.S. WTP for surface water quality improvements—a finding not available from prior published work or individual valuation studies viewed in isolation.

Results also highlight the risks involved in international site-to-site BFTs that do not capitalize on potential insights available through MA. In contrast to some past results that are more favorable for international site-to-site BFT prospects (e.g., Kristófersson and Navrud 2007), findings here suggest that site-to-site transfer between U.S. and Canadian sites would risk substantial generalization errors related to the systematic divergences in value surfaces between the two countries. Canadian WTP appears to be systematically lower than U.S. WTP for otherwise identical water quality improvement policies and contexts, at least considering the available sample of studies. Canadian studies also appear to have different WTP patterns related to baseline quality. Results such as these point to the risks of omitted variables and other biases in multinational MRMs that do not specify models to allow for at least some systematic variation in WTP across countries (e.g., Brander, van Beukering, and Cesar 2007, Santos 1998).

In contrast, in-sample convergent validity assessments provide at least preliminary evidence that multinational MA can provide a source of low-to-moderate error benefit transfers (Table 4). Such findings may be particularly relevant when the sample of studies available within a particular country precludes a good site-to-site match for

Table 5. Transfer Accuracy for Canadian Observations: Out-of-Sample U.S.-only Meta-Function Transfer

Canadian Obs.	Predicted WTP: Meta-function Transfer (2002 \$U.S.)	Primary Study WTP (2002 \$U.S.)	Absolute Value % Error (Meta-function Transfer)	Scenario ^a
1	\$254.60	\$41.86	508.26%	$WQ_non = 2.5, baseline = 4.5, lake=1$
2	\$254.60	\$23.30	992.59%	$WQ_non = 2.5, baseline = 4.5, lake=1$
3	\$150.52	\$13.88	984.46%	$WQ_non = 2.5, baseline = 4.5, lake=1, nonusers=1$
4	\$305.16	\$11.20	2625.45%	$WQ_fish = 0.5, baseline = 4.5, lake=1, fishplus=1$
5	\$305.16	\$21.98	1288.42%	$WQ_non = 0.5, baseline = 4.5, lake=1, fishplus=1$
6	\$180.41	\$6.60	2632.80%	$WQ_non = 0.5, baseline = 4.5, lake=1, fishplus=1, nonusers=1$
7	\$420.08	\$61.24	585.95%	$WQ_fish = 2.5, baseline = 4.5, lake=1, fishplus=1$
8	\$420.08	\$40.18	945.37%	$WQ_non = 2.5, baseline = 4.5, lake=1, fishplus=1$
9	\$248.35	\$19.96	1144.38%	$WQ_non = 2.5, baseline = 4.5, lake=1, fishplus=1, nonusers=1$
10	\$420.08	\$41.91	902.39%	$WQ_fish = 2.5, baseline = 4.5, lake=1, fishplus=1$
11	\$420.08	\$46.90	795.78%	$WQ_non = 2.5, baseline = 4.5, lake=1, fishplus=1$
12	\$248.35	\$21.56	1052.05%	$WQ_non = 2.5, baseline = 4.5, lake=1, fishplus=1, nonusers=1$
13	\$126.95	\$24.09	427.02%	$WQ_non = 0.25, baseline = 4.5, lake=1$
14	\$126.95	\$14.29	788.56%	$WQ_non = 0.25, baseline = 4.5, lake=1$
15	\$75.05	\$7.69	875.66%	$WQ_non = 0.25, baseline = 4.5, lake=1, nonusers=1$
16	\$75.55	\$15.07	401.34%	$WQ_non = 1, baseline = 7, regional_fresh=1$
Mean % Error (Absolute Value)			1059.41%	

^a Scenarios characterized by Canadian mean values for methodological variables and income. Other variables are set to zero unless otherwise noted.

standard benefit function or even unit value transfer. In such cases, multinational MA might offer an alternative means to generate transferable benefit functions. However, even in this case caution is advised, as studies with insufficient studies for domestic benefit transfers will likely provide a relatively small quantity of data for MA, thereby necessitating the type of small sample caveats emphasized here.

Taken together, model results provide a mixed message regarding the possibilities for valid and reliable international benefit transfer. Here, meta-function transfer allows adjustments for systematic WTP differences between the two countries, but limitations in the Canadian sample size preclude a more comprehensive analysis of systematically varying slopes for all moderator variables. As a result, there might be significant value surface differences between the two countries that remain unidentified by the current analysis. Moreover, results suggest the substantial errors that can occur in unadjusted transfers.

Future research will be required to provide more comprehensive analysis of such issues and to assess the most appropriate ways to leverage data from multiple countries to improve benefit transfer. Current results suggest that practitioners should exercise extreme caution in potential applications of site-to-site BFT between even similar and neighboring countries. While MA may assist practitioners in ameliorating some of the potential problems with international benefit transfer, additional work will be required to assess the broader capacity of multinational MA to promote valid benefit transfers. In the absence of this and other empirical evidence, the broader viability of international benefit transfer will remain uncertain.

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