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Examining tourist preferences to slow glacier loss: evidence from Alaska

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ABSTRACT

Climate change has affected the rate at which glaciers are receding around the globe. Much of the research on glacier loss has focused on its effects on rising sea levels and water supply. However, studies examining the impact of glacier loss on *in situ* ecosystem services are quite limited. The Mendenhall Glacier in the Tongass National Forest is an easily accessible glacier that receives over 600,000 visitors annually. While the glacier is currently visible from the visitor centre, it is expected to recede out of sight within the next few decades. Using a choice experiment, tourists are surveyed to estimate a willingness to pay value for slowing the rate of glacier recession. Results indicate that tourists are willing to pay, on average, $648 per year to reduce the annual rate of glacier loss to 0.15 km^3 over the next 60 years. Willingness to pay for policies to achieve the outcomes differs based on political preference and environmental organisation membership. Nature-based tourists care about preserving glaciers and disagree about the mechanisms for how to accomplish that objective.

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Glaciers; nature-based tourism; recreation; choice experiment; non-market valuation

Introduction

At present, glaciers cover approximately 10% of Earth's surface, and store an estimated 75% of its freshwater. It is well-known that the freshwater input from glacier melt is causing sea level rise. The National Snow and Ice Data Center estimates that if all land ice were to melt, the global sea level would rise about 230 feet.[1] There is a large economics literature projecting the magnitude of the impacts of sea level rise (Bosello, Roson, & Tol, 2007; Nováčková & Tol, 2018; Pycroft, Abrell, & Ciscar, 2016), and also consistent water availability (Carey et al., 2014; Gan, Luo, Zuo, & Sun, 2015; Vincent et al., 2017) resulting from melting glaciers. There is also a related literature studying the impacts of climate change on winter-based recreation (Beniston, 2012; Dawson & Scott, 2007, 2013; Scott, Dawson, & Jones, 2008; Scott, McBoyle, Minogue, & Mills, 2006), as well as glacier-based recreation (Demiroglu, Dannevig, & Aall, 2018; Purdie, 2013; Purdie, Gomez, & Espiner, 2015; Stewart et al., 2016; Welling, Árnason, & Ólafsdottír, 2015). However, studies exploring the impact of glacier recession on *in situ* ecosystem services, such as recreation, have been largely absent from the willingness to pay literature in economics.

Glacier-based recreation takes on a variety of forms. At the Mendenhall Glacier in Juneau, Alaska, over 600,000 annual visitors use the Mendenhall Glacier Visitor Center as their base of recreation (J. Neary, personal communication, February 14, 2018). The primary activity in which visitors engage-in is glacier viewing. Additional activities in which people engage-in on or in the vicinity of the glacier include hiking, cross-country skiing, and camping. At the Athabasca Glacier in British Columbia, visitors are able to board a vehicle that will transport them onto the toe of the glacier, and some of them also hike on the ice. People have long been skiing on inland glaciers in Europe, and there is evidence that summer season opportunities for this activity are diminishing (Kaenzig, Rebetez, & Serquet, 2016; Koenig & Abegg, 1997; Steiger, Scott, Abegg, Pons, & Aall, 2017).

The Begich, Boggs Visitor Center in the Chugach National Forest in South-central Alaska serves as a cautionary tale. It opened in 1986 with the Portage Glacier in view. By 1994, the glacier had receded out of sight, resulting in a substantial drop in visitation to the Visitor Center (O'Neel et al., 2015). Lost recreational value due to glacier recession is therefore potentially quite large. However, the economics literature on the impact of glacier loss specifically on recreation is quite sparse. Thiene and Scarpa (2009) use choice experiment data to estimate a positive willingness to pay (WTP) for hiking in European mountains when there is a glacier in the viewshed, but that value does not include changes in future glacier coverage. In a study related

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Supplemental data for this article can be accessed at http://dx.doi.org/10.1080/02508281.2019.1606978 to winter recreation, Sælen and Ericson (2013) use a choice experiment to estimate WTP for cross-country ski trips under different snow conditions in forests outside of Oslo, Norway. They found that worse snow conditions resulted in lower WTP for a trip. How much would people be willing to pay to reduce the rate at which the glacier is losing ice? This study provides an answer to that question by estimating a non-market value for *in situ* glacier ecosystem services using a sample of nature-based tourists.

Since the suite of ecosystem services provided by glaciers is not bought and sold in a market, a non-market valuation approach must be used to measure the economic value people place on changes in them. Ecosystem services are defined as services provided by an ecosystem that benefit at least one person (Boyd & Banzhaf, 2007). Economists measure the value of benefits using willingness to pay, which is the maximum amount people are willing to pay for a specific level of service provision. And while willingness to pay can be measured in any quantifiable unit, money is usually chosen because it is expressed in units that are commonly understood. In general, willingness to pay measures peoples' willingness to trade off things that they care about to obtain a positive incremental change in something. In this study, the positive change is the decreased rate at which glaciers are receding, so the estimated WTP values measure the extent to which people are willing to give up other desirable things so that glaciers will recede less quickly.

Two types of preference data can be gathered in the pursuit of non-market WTP values. The first is revealed preference data, in which researchers observe actual consumer behaviour. The second is stated preference data, in which the researcher elicits preference information directly from respondents, and that preference information is not based upon actual behaviour. Within stated preference elicitation methods, the most common are contingent valuation (Mitchell & Carson, 2013) and choice experiments (Adamowicz, Boxall, Williams, & Louviere, 1998). Choice experiments are useful when varying multiple attributes over multiple levels, particularly when respondents are asked to choose between different unfamiliar products (Carson, DeShazo, Schwabe, Vincent, & Ahmad, 2015; Interis & Petrolia, 2016). A choice experiment is well-suited for preference elicitation in this situation because there is uncertainty in potential glacier loss outcomes, and because there are multiple policies presented to obtain those outcomes.

There are those who would prefer that stated preference methods not be used to estimate WTP for ecosystem services. Some feel the environment has intrinsic value and that the protection of it is a moral imperative, independent of the value humans receive from it. Others question the assumption that choices made in hypothetical situations can be interpreted as a reflection of preferences, and therefore value. By extension, one can then question whether preference revelation gathered from hypothetical scenarios should inform policy (Diamond & Hausman, 1994; Shabman & Stephenson, 2000; Wainger, King, Cantrell, & Bird, 2004).

This study avoids wading directly into the debate about the normative issues surrounding WTP, and instead addresses the positive question of peoples' willingness to pay to reduce the rate at which glaciers are receding. This position is motivated by the recognition that non-market benefits stemming from the glacier ecosystems should probably be represented more frequently in environmental benefit–cost analyses, and if a particular ecosystem is providing a set of services that does not have a value associated with it, the implicit value assigned to that suite of ecosystem services in a benefit–cost analysis will be zero. With a value of zero, the suite of ecosystem services will likely be underprovided in society (Bockstael, Freeman, Kopp, Portney, & Smith, 2000).

A choice experiment (CE) is used to examine preferences for reducing the rate at which glaciers are receding due to climate change. The content of the survey is informed by the scientific literature studying glacier melt dynamics (Boyce, Motyka, & Truffer, 2007; Clarke, Jarosch, Anslow, Radić, & Menounos, 2015; Larsen, Motyka, Arendt, Echelmeyer, & Geissler, 2007; Motyka, O'Neel, Connor, & Echelmeyer, 2003; O'Neel et al., 2015) and the impacts of melting glacier ice on sea level rise (Carson et al., 2016; Meier et al., 2007; Neumann, Vafeidis, Zimmermann, & Nicholls, 2015). The choice experiment was administered at the Mendenhall Glacier Visitor Center (MGVC) outside of Juneau, Alaska. Two characteristics make the MGVC a plausible and realistic setting in which to gather preference information. First, at the time of the survey, one viewshed provided a stark contrast with a glacial landscape in the background and a post-glacial landscape in the foreground. If the Mendenhall Glacier retreats from view of the MGVC, people will only be able to see a post-glacial landscape. Second, the Mendenhall Glacier is losing volume at an increasing rate. Between 1995 and 2001, it lost an average of 0.08 km^3 of volume per year, which is equivalent to 32,000 olympic-sized swimming pools worth of liquid water. Between 2001 and 2007, the rate of mass loss increased to an average of 0.13 km^3, or 52,000 olympic-sized swimming pools worth of water (Mendenhall Glacier Facts, 2011). It is predicted that the average annual temperature over the Juneau Icefield will continue to increase, which means the increasing rate of glacier recession is expected to continue.

The rest of the paper has been organised in three sections. The first section outlines the choice experiment, survey administration, and the econometric model. Second section summarises the results of a random parameters logit model, as well as willingness to pay estimates, followed by discussion and conclusions.

Materials and methods

The choice experiment

The MGVC receives over 600,000 visitors each year, nearly all of whom disembark from cruise ships in downtown Juneau. The choice experiment design included four attributes: cost attribute; an attribute describing the rates of glacier loss, and two policy attributes to achieve the described rates of glacier loss. A summary of the attributes is shown in Table 1. The main outcome attribute is the rate of glacier loss. Between 2001 and 2007, the Mendenhall Glacier lost an average of 0.13 km^3 annually from its volume (Mendenhall Glacier Facts, 2011). Assuming the average rate of glacier loss has not decreased since measurements were last taken, glacier recession of 0.15 km^3/year was used as the 'best-case scenario' result. Other plausible rates of glacier recession over the next 60 years are 0.20, 0.25, and 0.35 km^3/year. While geographic-specific factors cause rates of glacier loss to vary substantially across individual glaciers, the range of glacier loss values in this survey was meant to be representative of the distribution of potential outcomes across different glaciers. Labao, Francisco, Harder, and Santos (2008) find that colour photographs reduce information bias. Hence, simulated colour photographs showing how the glacier might look in 60 years if the varying rates of glacier loss occur were included.

Two policy instruments were proposed to achieve the outcomes described in the survey. The first policy instrument presented was a global greenhouse gas (GHG) reduction agreement. This attribute contained three levels: no agreement, a limited abatement agreement, and a vigorous abatement agreement. A limited abatement agreement was defined as a binding international agreement in which all GHG emitting countries agree to modest reductions in GHGs. A vigorous abatement agreement was defined as a binding international agreement in which all GHG emitting countries agree to extensive reductions in GHGs. In addition to reducing the rate at which glaciers recede, reducing GHGs also brings with it many other concomitant benefits, such as improved health and catastrophe aversion. Because of these confounding effects, an insulated ice blanket was introduced as a second hypothetical policy instrument to help disentangle the local effects of GHG emissions reductions (decreased rates of glacier loss) from the global effects (concomitant benefits) of GHG emissions reductions.[2] Insulated ice blankets have been used by glacier dependent ski resorts in Europe to reduce summer ice melt (Olefs & Fischer, 2008). Respondents were given a description of ice blankets, and also shown a picture of an ice blanket covering a section of glacier so they could envision it being used in practice. By allowing respondents to choose from a menu of different combinations of GHG reduction and glacier blankets, all with different costs, the local effects of GHG reduction can be separated from the global effects.

The payment vehicle for the monthly household cost attribute was described as an increased cost of living, to be incurred both directly (e.g. more expensive gasoline) and indirectly (e.g. more expensive produce). Monthly programme costs ranged from \$5 to \$100. For a given rate of glacier loss, costs were randomised across choice scenarios. To avoid strict dominance within choice scenarios, it was always more expensive to achieve a greater reduction in the rate of glacier loss.

Table 1. Attribute levels used in survey.

Attribute	Levels used
Annual glacier loss (measured in volume)	0.15 km^3, 0.20 km^3, 0.25 km^3, 0.35 km^3
Insulating ice blanket	Yes, no
Climate agreement (CO_2 abatement)	None, limited, vigorous
Monthly program cost	\$0, \$5, \$10, \$20, \$25, \$40, \$50, \$60, \$100

Survey administration and sampling

The survey was broken into three sections. The first section asked preliminary screening and salience questions. Respondents answered questions about their knowledge on the link between GHG emissions and climate change, concomitant positive impacts of GHG emissions reductions other than climate change impacts, the impact of climate change on glaciers in Alaska, and finally the impact of climate change on future glacier loss in Alaska. The second section presented respondents with either two or four choice scenarios in which they were asked to make trade-offs between annual rates of glacier loss at a monthly cost to their household. Each choice scenario included five distinct choices. Each choice contained different levels of the four attributes, and a picture depicting what the glacier in front of them would look like in 60 years for a given rate of glacier loss. Each choice scenario contained one status quo option, for which the respondent paid nothing and resulted in the worst-case scenario of 0.35 km^3/year in glacier loss. The final section collected sociodemographic information. A sample choice scenario is shown in Figure 1.

Choice Scenario 1

	Program (A) No Action	Program (B) Ice blankets	Program (C) Limited GHG Reduction	Program (D) Limited GHG Reduction & Ice blankets	Program (E) Vigorous GHG Reduction
Policy	No reduction in GHG.	No reduction in GHG.	Reduces GHG.	Reduces GHG.	Reduces GHG more.
Ice blankets	No	Yes	No	Yes	No
Glacier Loss in the next 60 years	0.35km^3/yr	0.20 km^3/yr	0.20 km^3/yr	0.15 km^3/yr	0.15 km^3/yr
View after 60 years	Picture 4	Picture 2	Picture 2	Picture 1	Picture 1
Cost to HH/mo	$0	$10	$50	$60	$100
Preferred program:	☐	☐	☐	☐	☐

Figure 1. Example choice scenario.

Note: The full survey instrument can viewed in the on-line supplemental material to this paper.

The choice experiment was administered by pen and paper using random intercept sampling at the MGVC during the peak of the summer 2015 tourist season. Tourists at the MGVC are overwhelmingly comprised of cruise ship passengers, and represent a group of users for whom glaciers have recreational salience. To ensure the survey effort was spread across different types of tourists, both the time of day and day of the week during which surveying occurred was systematically staggered based on the cruise ship docking schedule.[3] While not a true random sample, this method provided a sample with reasonable heterogeneity of sociodemographic characteristics.

166 surveys were administered, 149 were completed, and after quality control measures were taken, 115 usable surveys remained.[4] Of the 115 reliable surveys, 37 saw four choice scenarios and 78 saw two choice scenarios, which resulted in 1520 observations. Descriptive statistics are presented in Table 2. Respondent characteristics were similar to Juneau visitors at-large during the same time period (Alaska visitor statistics program 7: Summer 2016, 2017). The average age of the sample is just over 61 years old, and 52% of the sample is female. The average income of the sample is $116,450, and 69% of the population had at least a bachelor's degree. While the sample mirrors the population of visitors reasonably well, it is not very representative of the overall U.S. population. The U.S. population is younger (median = 39.7 years old),[5] less white (sample = 96%; U.S. average = 76.9%), less wealthy (average per capita income = $29,829), and less educated (average = 30.3% with at least bachelor's degree)[6] than the sample of respondents.

Table 2. Summary statistics.

	Survey sample				Tourist
Variable	*N*	Mean	Min.	Max.	Mean
Age	113	61.34	24	82	56.2
Female	111	0.52	0	1	55
Income in 1000 USD	102	116.45	7.50	220	76.44
At least Bachelor's degree	115	0.69	0	1	29.6
Nonwhite	112	0.04	0	1	
Politically conservative	115	0.36	0	1	
Is retired	115	0.50	0	1	
Is unemployed	115	0.02	0	1	
Member of environmental organisation	115	0.44	0	1	
Is aware climate change caused by GHGs	115	0.97	0	1	
Is aware of climate change impacts on health and ecosystem	114	0.84	0	1	
Is aware of how climate change is impacting Alaska	114	0.67	0	1	
Topic has high salience to respondent	115	0.67	0	1	

Econometric approach

The choice experiment is based upon the Random Utility Maximization (RUM) Model, in which individuals are given a menu of alternatives comprised of different attributes and levels. Respondents then maximise their utility by choosing the alternative that gives them the greatest satisfaction (McFadden, 1974). U_{ijs}, which is the utility for individual *i* when faced with alternative *j* in choice scenario *s*, is given by

$$U_{ijs} = \alpha_{ijs} + \gamma t_{ijs} + \boldsymbol{\beta}'\mathbf{x}_{ijs} + \epsilon_{ijs} \quad (1)$$

where α_{ijs} is an alternative-specific constant; γ is the coefficient on the cost of alternative *t*, $\boldsymbol{\beta}'$ is a vector of coefficients on non-cost attribute levels $\mathbf{x}_{ijs}$, and ϵ_{ijs} is a stochastic error term. Assuming the stochastic term is distributed i.i.d. extreme value, parameters can be estimated using the Conditional Logit Model (CLM) (McFadden, 1974). The CLM assumes that within the choice scenarios, respondent utility is based solely upon the attributes of the choices and not upon the characteristics of the respondent. The CLM also assumes that choice probabilities are constant across individuals, so that coefficients are fixed.

An important limitation of the CLM is that it is subject to the independence from irrelevant alternatives (IIA) assumption (Greene, 2012). The Random Parameters Logit (RPL) relaxes the IIA assumption. In it, some or all parameters are allowed to vary randomly based on heterogeneity in the population sample. This allows the model to capture unobserved heterogeneity in preferences. It is also possible for utility to be correlated across alternatives in the random parameters logit model (Train, 2009). To construct the random parameters logit, the traditional conditional logit is adjusted to include an additional error term, η_{ijs}:

$$U_{ijs} = \alpha_{ijs} + \gamma t_{ijs} + \boldsymbol{\beta}_{\mathbf{i}}'\mathbf{x}_{ijs} + \epsilon_{ijs} + \eta_{ijs} \tag{2}$$

where η_{ijs} is a random term with zero mean, whose distribution depends on underlying data related to individual i and alternative j within a choice scenario, and estimated parameter values. The indirect utility function is linear in parameters, and the disutility of no change in the status quo is normalised to zero. For statistically significant parameters, willingness to pay for a marginal change in attribute k can be calculated as the attribute's estimated coefficient divided by the estimated cost coefficient: $WTP_k = \beta_k/\gamma$. In the RPL model, β_k is the mean of the distribution of estimated coefficients of the kth attribute.

Estimation results

Parameter estimates

Parameter estimates for the uncorrelated RPL, correlated RPL, and correlated RPL with interactions are displayed in Table 3 in columns 1, 2, and 3, respectively. The simulated likelihood is maximised in each model using 5000 Halton draws. Price and status quo are estimated as fixed parameters, while the rest of the parameters of interest are estimated randomly. For each random parameter, the underlying distribution is assumed to be normally distributed. The coefficients of the random parameters in Table 3 are the means of the normal distribution of estimates. The estimated standard deviations, which appear below the parameter estimates, describe the distributions around their mean values. For the uncorrelated RPL, the standard errors of the estimated standard deviations are obtained from the lower triangular matrix of the Cholesky factor. For the correlated RPL, the standard errors are calculated using the delta method (Hole, 2007; Train, 2009).

Between the first two models, the AIC, Log Likelihood, and McFadden's adjusted R^2 all favour the correlated RPL. An LR test is performed to confirm whether the off-diagonal elements of the variance-covariance matrix are jointly equal to zero. The test statistic, which is distributed χ^2_{10}, is (328−310) × 2 = 36, implying a rejection of the null hypothesis that the off-diagonal elements of the variance-covariance matrix are jointly equal to zero. This is consistent with Mariel and Meyerhoff (2018), who also find that not allowing random parameters to be correlated could lead to biased coefficient estimates. The results of the correlated RPL in column 2 are reported next.

Table 3. Main results.

	RPL No Corr	RPL Corr	RPL Corr interactions
Price	−0.054**	−0.103***	−0.105**
	(0.02)	(0.04)	(0.04)
Status quo	−1.113	−4.929***	−4.828***
	(0.70)	(1.63)	(1.68)
0.15 km^3 recession	2.743**	5.738**	8.398***
	(1.25)	(2.39)	(3.25)
0.20 km^3 recession	1.057*	3.254**	4.712**
	(0.55)	(1.47)	(1.86)
Ice blanket	−1.441*	−0.543	−2.090
	(0.77)	(1.28)	(1.93)
Limited CO_2 agreement	1.962*	8.339**	7.245*
	(1.11)	(3.93)	(4.30)
Vigorous CO_2 agreement	1.768	6.767	3.648
	(2.01)	(5.85)	(6.79)
Environmental organization membership ×			
0.15 km^3 recession			−2.562
			(2.70)
0.20 km^3 recession			−0.750
			(1.57)
Ice blanket			3.613**
			(1.64)
Limited CO_2 agreement			5.913**
			(2.94)
Vigorous CO_2 agreement			14.343**
			(5.66)
Conservative political preferences ×			
0.15 km^3 recession			−2.297
			(2.75)
0.20 km^3 recession			−2.679
			(1.63)
Ice Blanket			−1.550
			(1.49)
Limited CO_2 agreement			−5.295*
			(3.00)
Vigorous CO_2 agreement			−13.651**
			(5.94)
Standard deviations			
0.15 km^3 recession	4.787***	2.614	3.578
	(1.47)	(2.37)	(2.57)
0.20 km^3 recession	0.022	2.067	2.118*
	(0.59)	(1.28)	(1.26)
Ice blanket	2.730***	4.240***	3.319***
	(0.85)	(1.28)	(1.14)
Limited CO_2 agreement	3.767***	9.738***	8.297**
	(0.99)	(3.53)	(3.33)
Vigorous CO_2 agreement	6.568***	22.932***	20.060***
	(2.35)	(5.33)	(5.56)
N	1520	1520	1520
AIC	679	663	657
Log likelihood	−328	−309	−297
McFadden's adjusted R^2	0.201	0.221	0.184

Note: Standard errors in parentheses below parameter estimates; 95 CI next to WTP estimates. Results are from a random parameters logit with 5000 Halton draws. ***$p < .01$, **$p < .05$, *$p < .1$.

The first estimated parameter is price of the alternative, which represents the monthly cost of implementing the suite of programmes in each alternative. It is negative and statistically significant, which indicates respondents were less likely to choose an alternative as its price increased. The next estimated parameter is for *Status Quo*, or the 'no action' option, in which respondents paid nothing and received nothing. The estimated coefficient on that variable is negative and statistically significant, which indicates that respondents prefer some kind of action be taken to slow the rate at which glaciers are receding. The first of the random parameters is the smallest rate of glacier loss, 0.15 km^3 *recession*. The mean of its estimated parameter distribution is positive and statistically significant. Furthermore, the mean of the parameter estimates for 0.20 km^3 *recession* is also positive and statistically significant, though smaller in magnitude than the that of 0.15 km^3 *recession*. The first policy variable is the estimated coefficient on *Ice Blanket*, which is negative and not statistically significant. The estimated coefficient on *Limited* CO_2 *agreement* is statistically significant at the 10% level, while the coefficient on *Vigorous* CO_2 *agreement* is not statistically significant. The presence of a non-significant mean value and a significant standard deviation indicates that those attributes are likely valued differently by different groups of respondents. Indeed, the estimated standard deviations around all random parameters except for 0.15 km^3 recession are statistically significant, confirming that there is unobserved heterogeneity around the mean of the estimated random parameters.

Four salient observations arise from the RPL estimates. First, the statistically significant estimated coefficients in front of the glacier loss rates are positive and increasing in magnitude as the rate of glacier loss decreases. This indicates that, on average, respondents prefer that glaciers shrink less quickly. Second, the estimated coefficient in front of *Limited* CO_2 *agreement* is positive and statistically significant, while the the coefficient on *Vigorous* CO_2 *agreement* is not statistically significant. This suggests that respondents prefer a moderate GHG reduction strategy over a more extreme one. Third, the estimated coefficient on *Ice Blanket* is negative but not statistically significant. This suggests that while respondents are not favourably disposed to supporting that method of reducing the rates of glacier loss, there is too much noise in the data to extract a precise signal. Finally, the statistically significant estimated coefficient on status quo indicates that respondents have negative utility associated with choosing the status quo alternative, which contains the worst outcome and no policy action. While this result is inconsistent with some of the choice experiment literature (Adamowicz et al., 1998; Boxall, Adamowicz, & Moon, 2009), it is consistent with others (Patt & Zeckhauser, 2000; Petrolia, Interis, & Hwang, 2014).

Random parameters logit with interactions

After extensive testing among observable sociodemographic characteristics, political preference and membership in an environmental organisation were found to have an impact on which attributes respondents were willing to pay for. Indicator variables for political preferences and membership in an environmental organisation were interacted with the randomly varying outcome and policy variables, as shown in third column of Table 3. The estimated coefficients on these interactions with outcomes are not statistically significant, indicating that these sociodemographic factors do not help disentangle heterogeneous preferences for the randomly varying outcomes, and there is, on average, agreement between the two groups in their desire to reduce the rate at which glaciers are disappearing. On the other hand, policy interactions lend insight into where the two groups diverge.

The estimated coefficient on the interaction between conservative political preferences and a vigorous GHG reduction agreement is negative, large, and statistically significant. The estimated coefficient on the interaction between conservative political preferences and a limited GHG reduction agreement is also negative and statistically significant, though smaller in magnitude than for the vigorous GHG reduction agreement. These two coefficients indicate that while respondents with conservative political preferences are substantially less likely to choose an alternative when it contains a vigorous GHG reduction agreement as a policy to reduce glacier loss, they are less opposed to choosing an alternative when it contains a limited GHG reduction agreement. On the other hand, the estimated coefficient on the interaction between membership in an environmental organisation and a vigorous GHG reduction agreement is positive, large, and statistically significant. Further, the estimated coefficient on the interaction between membership in an environmental organisation and a limited GHG reduction agreement is positive and statistically significant. Interestingly, the group of respondents who declared membership in an environmental organisation were also more willing to choose an alternative when it contained an insulated ice blanket as a policy to reduce glacier loss.

Taken together, environmental organisation members are more willing to choose alternatives that contain the policies proposed in this study to reduce glacier loss, whereas respondents with conservative political preferences are less likely to choose those same policies. This occurred despite agreement between the two groups on the desire to reduce glacier loss.

Willingness to pay estimates

Estimating willingness to pay to reduce glacier loss, as well as the policies that achieve those outcomes, is a central focus of this research. Average willingness to pay estimates can be calculated as the estimated coefficient on outcomes and policies divided by the estimated cost coefficient ($\widehat{WTP}_k = \hat{\beta}_k/\hat{\gamma}$). These estimates, calculated for each model, are shown in Table 4, along with 95% confidence intervals in parentheses. The distributions are constructed by taking 10,000 random draws of the data, multiplying by the parameter estimates from the model, and calculating mean willingness to pay values. To formally test whether the willingness to pay distributions differ from one another, the complete combinatorial approach of Poe, Giraud, and Loomis (2005), in which two independent distributions obtained from simulation methods are compared for equality, is used. A one-sided test of willingness to pay differences between distributions is conducted and, where statistically significant, is noted.

Table 4. Willingness to pay.

	RPL	RPL with interactions
0.15 km^3 loss	\$54** (13, 189)	\$61** (11, 244)
0.20 km^3 loss	\$30** (7, 109)	\$33** (3, 141)
Status quo	−\$46** (−153, − 14)	–
Ice blanket	−\$4$^+$ (−46, 21)	−\$9$^+$ (−77, 22)
Limited GHG reduction agreement	\$78**$^+$ (21, 160)	\$77**$^+$ (12, 177)
Vigorous GHG reduction agreement	\$62 (−68, 161)	\$53 (−108, 164)

Note: 95% CI next to WTP estimates. **WTP distributions are different from zero at the 5% level or better, one-sided test. $^+$WTP distributions are different from each other at the 5% level or better, one-sided test.

Figures 2 and 3 show the distribution of WTP estimates for the RPL model with no interactions. There are three salient observations from Figure 2. First, it is clear that respondents prefer one of the action alternatives over the status quo, as is evidenced by the WTP distribution for status quo estimates falling below the WTP distributions for the other two outcomes. Poe tests confirm the difference between the status quo distribution and zero, as well as between status quo and the outcomes and policies. Second, among the action outcomes, respondents are willing to pay \$54 per month, or \$648 per year for the best outcome (0.15 km^3 recession), which is more than the \$360 per year they are willing to pay for the second-best outcome (0.20 km^3 recession). Third, there is more heterogeneity in preferences for the best outcome than for the second-best outcome. To explore that heterogeneity, several sociodemographic interactions were introduced into the model. For the best outcome, mean annual willingness to pay for respondents classified as old (defined as 65 or older) is equal to \$900, whereas it is \$612 for females. Members of environmental organisations are willing to pay an average of \$816 per year, while politically conservative individuals are willing to pay \$516.

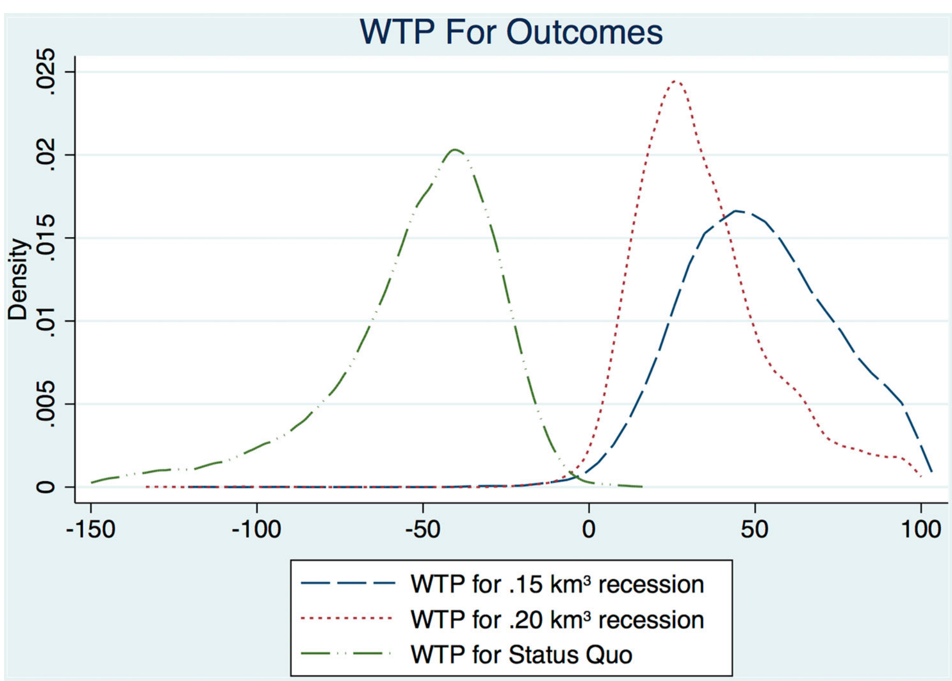

Figure 2. WTP for outcomes.

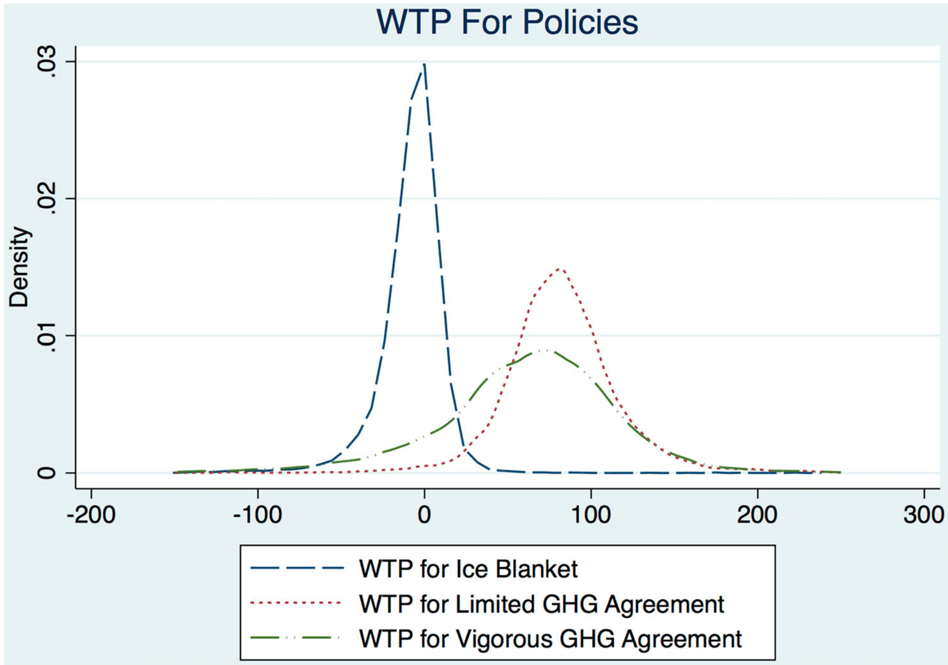

Figure 3. WTP for policies.

In terms of policies, Figure 3 shows that there is a lack of support for the insulated ice blanket policy, with an average WTP value less than zero, and the majority of the distribution mass falling below zero. It is not clear if respondents did not prefer the ice blanket because they did not want to see the glacier covered by it, or if they rejected the idea of using an ice blanket for another reason. Average WTP for a limited GHG reduction agreement is greater than WTP for a vigorous GHG reduction agreement, though there is much less agreement among respondents about the vigorous GHG reduction agreement than about the limited GHG reduction agreement, as is evidenced by the wider dispersion in the distribution of WTP for the vigorous GHG reduction agreement. To disentangle some of the roots of the unobserved heterogeneity in WTP for a vigorous GHG reduction with observed characteristics, indicator variables for political preferences and membership in an environmental organisation were interacted with the randomly varying outcome and policy variables. For a vigorous GHG reduction agreement, the average annual WTP for conservatives is −$ 46, while the average willingness to pay for those belonging to an environmental organisation is $ 97. The Poe test indicates that the difference in WTP distributions between the two groups is statistically significant.

Discussion and conclusions

To the best of the author's knowledge, this is the first study to directly estimate a willingness to pay value for glacier-based ecosystem services *in situ*. The majority of the world's glaciers are rapidly disappearing, and the primary cause is climate change. Most of the economic research on glacier loss has focused on the concomitant downstream impacts of sea level rise and water availability. Using a choice experiment that utilises the stark contrast between a glacial and post-glacial landscape, this study presents empirical evidence that a sample of tourists is willing to incur higher present and future costs to preserve *in situ* glacier ecosystem services. Willingness to pay estimates are statistically different than zero for both glacier loss outcomes, as well as for the limited GHG reduction agreement. The main results reveal that respondents are willing to pay, on average, $54 per month, or $648 per year in increased cost of living expenses to reduce the annual rate at which glaciers are receding to 0.15 km^3. They are also willing to pay $30 per month, or $360 per year to slow annual glacier loss to 0.20 km^3. If one were to conservatively discount the WTP value for 0.15 km^3 recession at 3% over the sixty-year timeframe indicated in the survey, the result is approximately $10.8 billion for a single glacier. Further, this is likely an underestimate since respondents are all users. There is likely non-use value associated with glaciers not capture by this study. By not accounting for these additional ecosystem service values, any calculation of the total benefits of glacier ecosystem services is certainly underestimated.

In terms of policy, respondents clearly prefer some action be taken to reduce the rate of glacier loss. The mean WTP for the status quo ('no action') option was −$ 46 per month. Moreover, respondents exhibited a positive WTP for a binding GHG reduction agreement. Average WTP for a limited GHG reduction agreement was higher than that for a vigorous GHG agreement ($78/month versus $62/month). While there was more consensus over support for a limited GHG reduction agreement, different groups of respondents had very different opinions about a vigorous GHG reduction agreement. The survey was fielded in 2015 around the time that the debate over whether countries should join the Paris Climate Accord was taking place. The split in support for the vigorous GHG agreement is consistent with polls from that time. A *New York Times* poll from November 2015 showed two-thirds of the U.S in support of joining some kind of binding international GHG reduction agreement, with a majority of Republicans opposed (Russonello, 2015). In a June 2015 study, *The Guardian* reported on a survey of 10,000 citizens of developed and developing nations, and found similar support for a binding international agreement, with slightly more support from developing than developed countries (Howard, 2015).

The results of this study are limited to this application, and caveats apply. First, WTP values are likely inflated due to the social desirability bias, which is the tendency of respondents in hypothetical studies to engage in pro-social behaviour by choosing the 'correct' answer (Dolnicar & Grün, 2013; Fisher, 1993; King & Bruner, 2000; Nederhof, 1985). Second, while the sample is representative of visitors to Juneau, it is not representative of the national population. Future research is needed to examine willingness to pay for reducing glacier loss among a broader section of the U.S. population, as well as citizens of non-U.S. countries. Finally, some people are opposed to using WTP to measure benefits from environmental improvements. While this study did not address that opposition, future WTP studies should incorporate questions to control for possible scenario rejection based on philosophical grounds.

This study has policy implications at the local and national level. From a nature-based tourism and recreation standpoint, investments in infrastructure that support recreational exposure to glaciers, such at the Mendenhall Glacier Visitor Center and Recreation Area where these surveys were fielded, would increase societal welfare by providing increased access to *in situ* glacier ecosystem services. At the national level, the policy implications are clear. Respondents prefer the rate at which glaciers are disappearing to slow, and they prefer an international GHG reduction agreement be used to accomplish that goal. Future research is needed to measure potential benefits from specific adaptive infrastructure improvements to provide improved tourist access to glaciers. In the local case of the MGVC, a choice experiment could be used to measure by how much would users and non-users might benefit from building a new visitor centre in a location where the glacier would be visible for a longer period of time into the future. More broadly, the ecotourism industry has seen an increase in interest towards experiencing charismatic environmental features, such as glaciers, before they disappear. While there exists market data that could be used to measure the use value of those experiences, market data does not capture non-use values. Choice experiments could be used in future studies to understand non-use values associated with glaciers as society attempts to uncover just how valuable they are.

Notes

1. https://nsidc.org
2. The insulated ice blanket is a costly policy to implement. While it is not practical to cover an entire glacier in an insulated ice blanket, it was meant to represent a potential adaptation strategy distinct from a global GHG reduction agreement.
3. http://claalaska.com/.
4. Some respondents in the sample did not provide complete sociodemographic information. As these specific characteristics were not explicitly included in the analysis, the results were unaffected by this.
5. www.statista.com
6. www.census.gov

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