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RESEARCH ARTICLE

Willingness-to-Pay for Rationed Goods: Bobcat Harvest Permits in Indiana

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Abstract

We use contingent valuation to estimate hunter and trapper willingness to pay (WTP) for a hypothetical bobcat harvest permit being considered in Indiana. Harvest permits would be rationed, with limits on aggregate and individual harvests. A model of permit demand shows that WTP may be subject to "congestion effects" which attenuate welfare gains from relaxing harvest limits. Intuitively, relaxing limits may directly change an individual's expected harvest and, hence, WTP. Participation may subsequently change, with congestion offsetting welfare increases. These effects may lead to apparent scope insensitivity that may be endemic in the context of rationed goods.

1. Introduction

Management of Indiana bobcats with a closed harvest season has resulted in the population growing substantially after declining for decades due to agricultural development and unregulated harvest (Johnson et al., 2010). Bobcat sightings have been reported in nearly every Indiana county (INDNR, 2022) and recent research in the state has been conducted to create a bobcat population model (Jones et al., 2020; Jones et al., 2022a; 2022b). With a growing population in portions of the state (Johnson et al., 2010), there is increased pressure to allow some regulated hunting and/or trapping. The Indiana Department of Natural Resources' (INDNR) mission is to enrich the quality of life for present and future generations by balancing the biological, ecological, recreational, and economic benefits of Indiana's fish, wildlife, and habitats (INDNR, 2023). This means, like with many state agencies, if there is interest in regulated hunting and trapping of a species and it can be done while maintaining the population, the agency may consider a regulated hunting and/or trapping season. Therefore, it is important for wildlife managers to understand hunter and trapper demand for harvesting bobcats when considering management options.

To this end, we use the contingent valuation method (CVM) to estimate willingness to pay (WTP) for a hypothetical bobcat harvest permit among resident Indiana hunters and trappers. CVM has been used to analyze new markets and demands for recreation permits (Sutton et al., 2001). The methodology has been used to estimate WTP for wildlife, allowing wildlife managers to set harvest regulations more efficiently. For example, Adhikari et al. (2023) and Ufer et al. (2022) use CVM to value programs to fund chronic wasting disease control in Tennessee and Michigan,

respectively. Mattsson et al. (2014) use CVM to value moose hunting in Sweden. Brunke et al. (2006) use CVM to estimate hunter demand and WTP for hypothetical fall and spring turkey hunting licenses in Mississippi. Sutton et al. (2001) use CVM to estimate angler WTP for fishing licenses and determine how prices affect angler access and regulator revenues. Sutton et al. (2001) emphasize the importance of balancing regulator profits from license sales with angler participation. In terms of predatory wildlife species, CVM has predominantly been used to estimate the value of preservation of an endangered or protected species. For example, Broberg and Brännlund (2008), Ericsson et al. (2008), and Chambers and Whitehead (2003) use CVM to estimate WTP for wolf preservation.

We mailed a questionnaire to 2,000 registered Indiana hunters and trappers with a detailed description of a proposed bobcat harvest season structure. We then presented them with a single-bounded dichotomous choice question asking whether they would buy a permit to participate in the described season. We used responses to this question to estimate the distribution of WTP using standard discrete choice estimators. We find mean WTP for a permit with a bag limit (or maximum harvest per person per season) of one animal and a statewide harvest quota (or the limit on the aggregate annual harvest of bobcats) of 300 animals to be \$13.50. To our knowledge, no prior work estimates WTP for bobcat harvest permits in Indiana or elsewhere.

Best practice in conducting a CVM study is to demonstrate validity of the WTP estimates by testing for consequentiality and scope effects. Consequentiality implies that respondents who believe the survey results will impact policy have different WTP than those who do not hold such beliefs (Herriges et al., 2010; Interis and Petrolia, 2014). Scope effects are present whenever WTP varies systematically with the quality or quantity of a good (Johnston et al., 2017). Testing for scope effects in the context of rationed goods like a hunting permit is not straightforward, however. Intuitively, hunter utility and, hence, welfare should increase with the number of animals they expect to harvest. Yet harvests are limited in aggregate by statewide quotas and individually by bag limits that restrict the number of animals a single hunter can take. We show that relaxing either quotas or bag limits can create general equilibrium effects that have countervailing impacts on expected harvest, clouding interpretation of scope effects. To our knowledge, this has not been noted in prior research. We explore how individuals respond to changes in bag limits and quotas and find that the resulting scope effects are consistent with intuition. Our discussion clarifies the role of these variables in testing for scope effects in the provision of rationed goods.

2. A theoretical model of bobcat harvest permit demand under rationing

We start by deriving a random utility maximization (RUM) model of bobcat harvest permits under rationing. Assume a regulatory agency sets a statewide harvest quota of x_1 bobcats. The quota limits the total number of bobcats that can be harvested in aggregate by all hunters within a given season; there is no restriction on the quantity of harvest permits sold, but we assume the harvest season ends when the x_1th bobcat is harvested.[1] Harvests by a single individual are subject to a bag limit, x_2. We, therefore, let $\mathbf{X} = [x_0\ x_1\ x_2]$ denote the vector of harvest permit attributes including a constant term, x_0, that accounts for other, unobserved factors that influence the utility from harvesting relative to the utility from not purchasing a permit.

The number of licensed hunters, or those who decided to purchase a permit at a given price p, is n. The expected harvest for a hunter who purchases a permit is $H(\mathbf{X}, n)$, where we assume $H_{x_1} > 0$ and $H_n < 0$. Intuitively, the expected harvest is increasing in the quota because a larger quota means hunters are more likely to harvest an animal prior to the quota being met in aggregate. Conversely, the expected harvest decreases with the number of hunters because a fixed quota is

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[1]This is consistent with the procedure being considered for bobcat harvests in Indiana and also matches the procedure used for regulating other species in the state. For example, harvests of river otters must be reported online within 24 hours. Prior to setting traps each day, trappers must check the IDNR website to confirm whether the season is still open. Harvests that take place after the season is closed are subject to forfeiture or other penalties.

more likely to get filled before a hunter can successfully fill their own bag limit. The sign of H_{x_2} is ambiguous. If the quota binds, a larger bag limit may reduce one's expected harvest; everyone's ability to harvest more animals implies the quota may be filled more quickly, and hence an individual hunter may have fewer chances to harvest his or her own animals. If the quota does not bind, then increasing the bag limit will increase harvest.

Let the utility hunter i receives be $U_i(H_i(\mathbf{X}, n), y_i; \mathbf{Z}_i) + \varepsilon_i$, where y_i is the hunter's income absent any permit expenditures, $\mathbf{Z}_i$ is a K-dimensional vector of personal characteristics, and ε_i is an unobserved shock. We assume $\partial U_i / \partial H$, $\partial U_i / \partial y_i \geq 0$. The probability hunter i chooses to purchase a permit with attributes $\mathbf{X}$ and price p is

$$\pi(\mathbf{X}, n, y_i, p, \mathbf{Z}_i) = \Pr\big(U_i\big(H_i(\mathbf{X}, n), y_i - p; \mathbf{Z}_i\big) + \varepsilon_{i1} \geq U\big(0, y_i; \mathbf{Z}_i\big) + \varepsilon_{i0}\big) \tag{1}$$

where the subscript on ε denotes different states of the world (i.e., whether the hunter purchases a permit or not). Of course, n depends endogenously on $\pi(\cdot)$. Let the total number of potential hunters in the market for a permit be N. Then

$$n = N \int \cdots \int \pi(\mathbf{X}, n, y, p, \mathbf{Z}) f(\mathbf{Z}, y) \mathrm{d}z_1 \cdots \mathrm{d}z_K \mathrm{d}y, \tag{2}$$

where $f(\cdot)$ is the joint density of the hunters' demographic characteristics. The equilibrium number of hunters, $n(\mathbf{X}, p, N)$, solves (2). We can then rewrite the representative hunter's utility with the permit as $U\big(H_i\big(\mathbf{X}, n(\mathbf{X}, p, N)\big), y_i - p; \mathbf{Z}_i\big)$. A first-order Taylor series expansion of $U(\cdot)$ around some arbitrary $\tilde{\mathbf{X}}$, $\tilde{p}$, $\tilde{y}_i$, and $\tilde{N}$ yields

$$U(\mathbf{X}, y_i - p, N) \approx \alpha_i + \boldsymbol{\beta}'_i \mathbf{X} - (\mu_i - \lambda_i)p_i + \mu_i y_i + \theta_i N, \tag{3}$$

where

$$\alpha_i = \left[\begin{array}{c} U_i - \sum_j \frac{\partial U_i}{\partial H_i}\left(\frac{\partial H_i}{\partial x_j} + \frac{\partial H_i}{\partial n}\frac{\partial n}{\partial x_j}\right)\tilde{x}_j - \frac{\partial U_i}{\partial H_i}\frac{\partial H_i}{\partial n}\frac{\partial n}{\partial y_i}\tilde{p} \\ - \frac{\partial U_i}{\partial y_i}\big(\tilde{y}_i - \tilde{p}\big) - \frac{\partial U_i}{\partial H_i}\frac{\partial H_i}{\partial n}\frac{\partial n}{\partial N}\tilde{N} \end{array} \right]\Bigg|_{\tilde{\mathbf{X}},\tilde{p},\tilde{y}_i,\tilde{N}}, \tag{4a}$$

$$\beta_{ij} = \frac{\partial U_i}{\partial H_i}\left(\frac{\partial H_i}{\partial x_j} + \frac{\partial H_i}{\partial n}\frac{\partial n}{\partial x_j}\right)\Bigg|_{\tilde{\mathbf{X}},\tilde{p},\tilde{y}_i,\tilde{N}}, j = 0, 1, 2, \tag{4b}$$

$$\mu_i = \frac{\partial U_i}{\partial y_i}\Bigg|_{\tilde{\mathbf{X}},\tilde{p},\tilde{y}_i,\tilde{N}}, \tag{4c}$$

$$\lambda_i = \frac{\partial U_i}{\partial H_i}\frac{\partial H_i}{\partial n}\frac{\partial n}{\partial y_i}\Bigg|_{\tilde{\mathbf{X}},\tilde{p},\tilde{y}_i,\tilde{N}} \tag{4d}$$

and

$$\theta = \frac{\partial U}{\partial H}\frac{\partial H}{\partial n}\frac{\partial n}{\partial N}\Bigg|_{\tilde{\mathbf{X}},\tilde{p},\tilde{y}_i,\tilde{N}}. \tag{4e}$$

Substituting (3) into (1) and simplifying yields $\pi_i = \Pr\big(\boldsymbol{\beta}'_i \mathbf{X} + \eta_i p_i \geq -[\varepsilon_{i1} - \varepsilon_{i0}]\big)$, where $\eta_i = -(\mu_i - \lambda_i)$. Assuming the difference in error terms follows a logistic distribution, we can estimate this choice probability using a standard logit model. Note that heterogeneity in preference parameters $\boldsymbol{\beta}_i$ and η_i can be attained in general via a random parameter or mixed logit approach or by simply interacting the permit attributes $\mathbf{X}$ by respondent characteristics $\mathbf{Z}_i$. We use the latter approach when presenting estimates later. The definitions of the parameters in (4a)–(4e) inform our discussion of scope effects below.

Given estimates $\hat{\boldsymbol{\beta}}_i$ and $\hat{\eta}_i$, and noting that $E(\varepsilon_{i1} - \varepsilon_{i0}) = 0$ given our distributional assumption, mean WTP for a permit with attributes $\mathbf{X}$ is

$$E(WTP_i) = \int \cdots \int \hat{\boldsymbol{\beta}}_i' \mathbf{X}/|\hat{\eta}_i| f(\mathbf{Z}) \mathrm{d}z_1 \cdots \mathrm{d}z_K. \tag{5}$$

3. Survey and data

We estimate (5) for a bobcat harvest permit using data from a mail survey of 2000 Indiana hunters and trappers in summer 2021 following the protocols outlined by Dillman et al. (2014). Respondent addresses were randomly drawn from the INDNR's license sales database. Because relatively few people trap in Indiana, we oversampled trappers by sending half of the questionnaires to those who purchased a trapping license and the other half to those who purchased a hunting license.[2] The INDNR uses 10 regional management units (RMUs) consisting of similar counties for managing deer populations and harvest (Swihart et al., 2020). RMUS 3, 4, and 9 (Fig. 1) were oversampled as the INDNR is sponsoring intensive wildlife population modeling and economic research in these regions. Our survey is a component of these efforts, and hence we attempted to ensure our data adequately captures preferences of sportspersons in these areas.[3] Twice as many respondents were solicited from the aforementioned RMUs due to the predator-prey relationship between bobcats and deer. The 1,000 trapper addresses represent 21.5% of licensed trappers in the state. By contrast, the 1,000 hunter addresses represent less than one percent of licensed hunters. This oversampling is important because trapping is the primary means by which we expect bobcats would be harvested in Indiana. Of the active furbearer harvesters responding to our survey, only 19% exclusively harvest furbearers through hunting, 37% harvest exclusively through trapping, and the remaining 44% both hunt and trap. Of our respondents, 121 reported that they hunted and trapped in the most recent season.

The questionnaire consisted of five sections. The first section collected general information about respondents' furbearer harvesting activities and contained the CVM question; we describe this question in detail below. Sections 2 and 3 asked about respondents' travel and equipment expenses relating to furbearer hunting and trapping, respectively. Section 4 asked respondents to provide their opinions on furbearer hunting or trapping using a Likert scale to gauge levels of agreement. Section 5 collected demographic information, including gender, age, race, household income, and education. A copy of the questionnaire is provided in Appendix A.

In Section 1, respondents were given a description of a proposed bobcat season that outlined regulations including locations of legal harvest, statewide quota, individual bag limits, harvest equipment, and proposed procedures for checking in harvested bobcats. After this description, respondents were asked if they would be willing to purchase a bobcat permit for a given, experimentally-generated price. Figure 2 provides an example of this question. The permit price was randomly drawn for each respondent from a distribution comprising values $6.75, $9.25, $11.25, $19.25, $24, and $45 per year.[4] For context, the smallest price is the same as that of existing

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[2]Hunting licenses in the state of Indiana allow harvest of small game species (e.g., rabbits and squirrels), birds (e.g., doves and pheasants), and furbearers (e.g., coyotes, foxes, raccoons, opossums) exclusively through hunting methods.

[3]A *t*-test finds respondents from RMUs 3, 4, and 9 are 6 percentage points more likely to identify as white and have incomes that are 10% smaller than those from other RMUs. Otherwise, the differences between the demographic characteristics of these groups of respondents are not statistically significant.

[4]Non-integer-valued prices are not unusual for harvest permits in Indiana. For example, the current price of a combined hunting and fishing license for disabled veterans is $2.75 per year. Waterfowl and Game Bird stamps were $6.75 per year until 2022. Fishing license prices were $14.25 per year until the mid-2000s. We therefore do not believe that non-integer prices seemed unfamiliar or posed unreasonable cognitive demands on respondents, all of whom are licensed sportsmen and -women. We were sure to round prices to the nearest quarter for consistency with past real-world license prices.
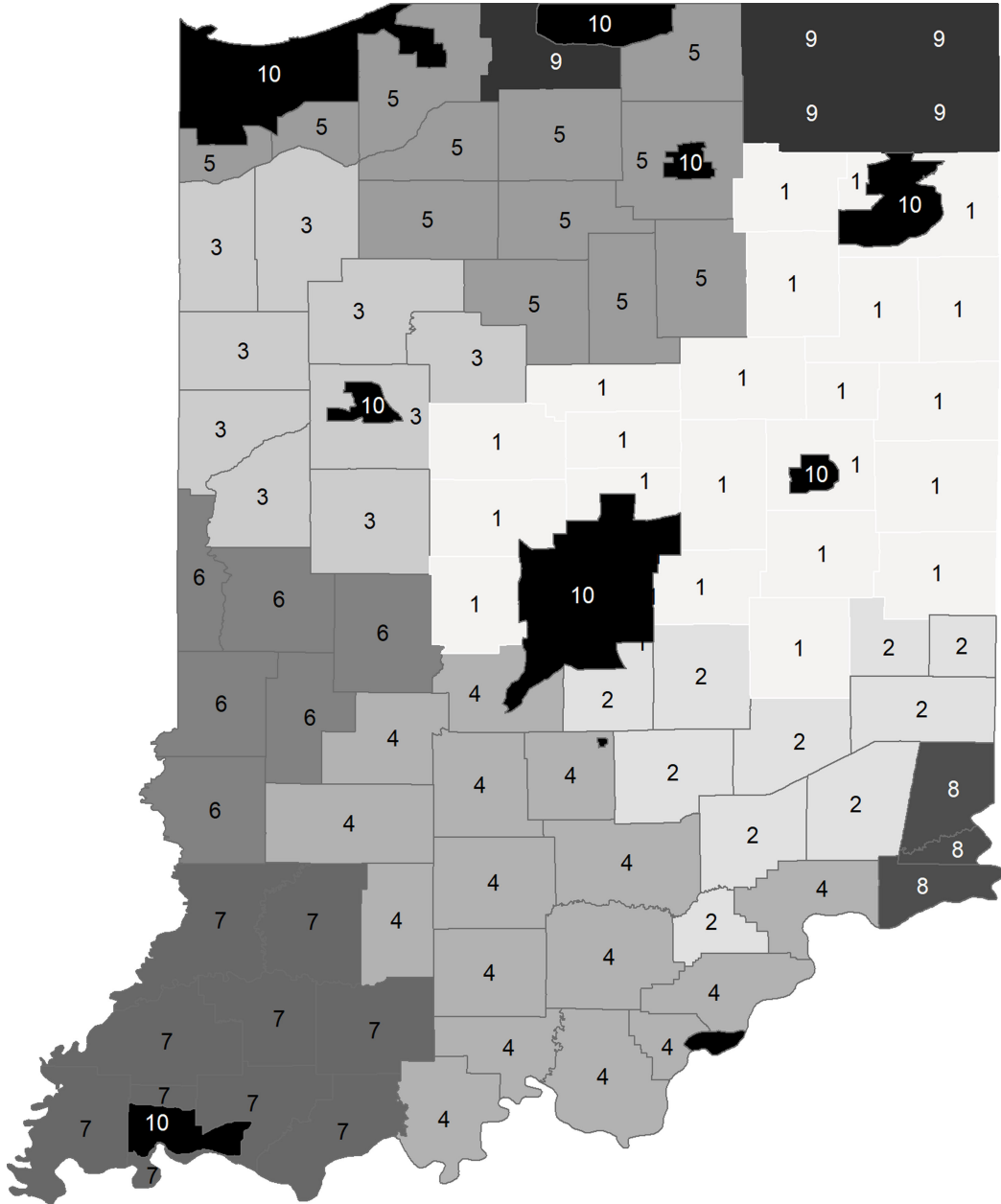
Figure 1. Regional management units for Indiana.

hunting stamps in Indiana (e.g., game bird habitat or waterfowl stamps, both of which are $6.75).[5] The largest price is approximately double that of existing large game permits (e.g., deer permits are $24 and turkey permits are $25). Prices in other Midwestern states range from approximately $5 to $10 for permits with similar bag limits, quotas, and seasons, although many other states

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[5]Hunting stamps represent an enhancement of a standard hunting license which, when purchased, allow harvest of additional game species not covered by the standard license. These work similarly to the way we described the bobcat harvest permit in Fig. 2.

The Indiana DNR is currently considering creating a bobcat hunting and trapping season. <u>Bobcat hunting and trapping is not currently legal in the state of Indiana.</u>

If introduced in Indiana, the bobcat season would open during the first week of November and close at the end of January or when the harvest quota is met—whichever is earlier. Harvests would be allowed in approximately 30 counties south of I-70.

The proposed harvest quota is XXX animals per season, with a bag limit of X bobcat(s) per person per season. The Indiana DNR estimates that this number of bobcats can be sustainably harvested each year at the current bobcat population level. The season will end early if the quota is reached prior to the season closing date. Hunters and trappers will be responsible for knowing if the quota has been met. The reported harvest will be tracked daily, and hunters and trappers may check the quota at any time online or by phone. If the season closes early, an exception may be made for an individual who harvests a bobcat within 48 hours after the close of the season and has not yet reached their bag limit.

Bobcats may be harvested with any firearm legal for coyotes, archery equipment, or any legal traps (foothold, snares). All other regulations would be the same as those for harvesting other furbearers. Once a bobcat is harvested, it must be checked in online within 24 hours. The carcass must be registered in person no later than 15 days after the month of harvest.

Bobcat licenses would need to be purchased in addition to a standard or lifetime trapping license or general hunting license. Bobcat licenses would be sold at local retailers and over the internet via the Indiana Fish & Wildlife Online License System. Licenses would be valid for a single season. License revenues will be used to support public land and wildlife habitat management, research, and improvement of recreational opportunities within the state of Indiana.

Indiana DNR officials will take your responses below into account when deciding whether to create a bobcat season and how much to charge for a license.

1.1.   Would you pay **$XX** for a bobcat license if Indiana created the bobcat hunting and trapping season described above?

□ Yes   □ No

1.1.1. If you selected "No" for question 1.1, please indicate why. (Check all that apply.)

□ The license price is too high.   □ The harvest quota is too low.

□ The bag limit is too low.   □ The harvest quota is too high.

□ I am not interested in harvesting a bobcat.

□ Other (please explain):_____

Figure 2. Bobcat willingness to pay question with randomly varying quotas, bag limits, and license prices presented to respondents.

(e.g., Michigan, Illinois, and Wisconsin) allocate licenses via lotteries and hence these prices simply represent application fees. In any case, as price equals marginal WTP at equilibrium, we believe our price range provides reasonable coverage of the distribution of WTP.

The use of a single dichotomous choice question to elicit WTP is standard and incentive-compatible (Carson and Groves, 2007; Freeman, 2003). Other elicitation formats (e.g., double-bounded dichotomous choice, payment card, or experimental auction) would provide more information. However, the single-bound dichotomous choice format fits the nature of the goods being valued in our CVM problem; hunters and trappers are used to paying a single, stated price for a harvest permit. Alternative formats risk making the decision problem seem unrealistic.

The "baseline" bobcat permit has a bag limit of one animal and a statewide quota of 300. In our survey, the statewide quota varied randomly among respondents, with half receiving a quota of 300 and half of 600. The bag limit also varied randomly among respondents and independently of price and quota, with half receiving an individual bag limit of one and half a bag limit of two. The bag limits and statewide quotas were suggested by INDNR biologists and deemed as reasonable

1.1.3.   Please rate your level of agreement/disagreement with the following statements.

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
My response will affect whether Indiana creates a bobcat season.	☐	☐	☐	☐	☐
The overall results of this survey will affect whether Indiana creates a bobcat season.	☐	☐	☐	☐	☐
The DNR will actually charge $XX for a bobcat license if Indiana creates a bobcat season.	☐	☐	☐	☐	☐

Figure 3. Consequentiality questions presented to respondents.

parameters for initial bobcat harvests. Variation in the quota and bag limit, akin to a 2×2 experimental design, allows us to test for scope effects.

Following the payment question, respondents who indicated they would not purchase a permit were asked a follow-up question to determine why they would not do so, which aided in identifying protest responses. Finally, we asked respondents a series of Likert scale questions to gauge how they felt their responses would impact the creation of a bobcat permit in Indiana. The questions asked if respondents felt i) their responses would affect the creation of a bobcat season; ii) overall survey responses would affect the creation of a bobcat season; and iii) the INDNR would charge the price the respondent was presented for a bobcat permit if a season was created (Fig. 3). These questions were meant to assess consequentiality and are a standard means of assessing the validity of responses to CVM questions (Johnston et al., 2017).

We pretested the survey using three focus group discussions conducted via Zoom in May 2021. Participants comprised experienced furbearer hunters and trappers known to INDNR biologists and included four furbearer trappers and an individual who both hunted and trapped furbearers. Participants completed our draft survey beforehand and gave us feedback on each question during the discussion. The final draft of the survey shown in Appendix A reflects this feedback. We chose our price distribution based on focus group feedback using a modification of the CVM question in Fig. 2. Formally, we used an open-ended question asking participants to state their WTP for the bobcat permit we described. We recorded their responses and fit a PERT distribution to these data. The prices we chose correspond with the 0th, 15th, 30th, 70th, 85th, and 100th percentiles of the fitted distribution.

Following Dillman et al. (2014), we initially mailed the questionnaire to respondents on July 2, 2021, followed two weeks later by a reminder postcard. We mailed a second questionnaire to nonrespondents two weeks after the reminder postcard. In total, we received 422 responses. We subsequently screened out those we judged to be protest responses (identified by selection of multiple responses when only one response was requested, inclusion of offensive comments in the survey, returning a blank survey, or returning a cover letter only and/or an offensive letter). We identified 15 surveys as protests, and an additional 8 respondents did not answer the WTP question, leaving us with 399 usable responses. Although this 20% response rate is lower than typical for surveys of wildlife-associated recreation, response rates in this literature have been trending downward (Stedman et al., 2019) and are usually lowest in surveys that include stated preference questions (e.g., Whitehead, 1993; Melstrom and Kaefer, 2020).

Table 1 presents respondent demographics. Our respondents were predominantly white (97%) and male (98%), without a post-secondary degree (62%), with a household income of less than $100,000 annually (74%), and with an average age of 52.6 years. This is broadly consistent with the distribution of hunter characteristics for the US as a whole (see the final column in Table 1; US

Table 1. Demographic information from the 399 survey respondents

Attribute	Sample proportion[a,b]	NSFHWAR proportion[a,c]
Gender		
Male	0.98*	0.90
Female	0.02*	0.10
Other	0.00	0.00
Mean age (years)	52.58*	46.74
Education		
Less than grade 11	0.04*	0.10
High school or equivalent	0.36*	0.31
Some college[c]	0.22	—
Associate's degree or equivalent[c]	0.17*	0.26
Bachelor's degree	0.15*	0.22
Graduate/professional degree	0.06*	0.12
Race		
White	0.97	0.98
Hispanic or Latinx	0.00	0.00
Black or African American	0.00	0.00
Asian	0.00	0.00
American Indian or Alaskan Native	0.00	0.00
Pacific Islander or Native Hawaiian	0.00	0.00
Multi-racial	0.00	0.00
Prefer not to answer	0.03	0.00
Household income		
< $20,000	0.03	0.04
$20,000 - $29,999	0.05*	0.03
$30,000 - $39,999	0.06	0.06
$40,000 - $49,999	0.08	0.11
$50,000 - $74,999	0.28	0.27
$75,000 - $99,999	0.22	0.19
$100,000 - $149,999	0.16	0.16
$\geq$ $150,000	0.10*	0.14

[a]Figures may not sum to one due to rounding.
[b]Superscript * denotes sample estimates that differ from population estimates at the 5 percent level or better.
[c]NSFHWAR refers to the 2016 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. This data reports the proportion of individuals with 1–3 years of college. This is equivalent to the sum of our "some college" and "associate's degree or equivalent" figures. We therefore combine these estimates when comparing against the population data.

DOI et al., 2016); nationally, hunters are predominantly middle-aged (46.7 years old) white (98.2%) males (90.3%), without a bachelor's degree (66.6%) and earn an annual household income of less than $100,000 (70.3%). However, tests of proportions indicate that our sample is more male, older, and less well-educated.

Table 2. Balance table showing demographics for each treatment[a,b]

Attribute	Bag limit = 1, quota = 300	Bag limit = 2, quota = 300	Bag limit = 1, quota = 600	Bag limit = 2, quota = 600
Gender				
Male	0.990	0.957	0.970	0.990
Female	0.010	0.043	0.030	0.010
Other	0.000	0.000	0.000	0.000
Age (mean, in years)	52.09	53.25	51.61	53.41
Race				
White	0.970	0.935*	0.970	0.990*
Hispanic or Latinx	0.000	0.000	0.000	0.000
Black or African American	0.000	0.000	0.000	0.000
Asian	0.000	0.011	0.000	0.000
American Indian or Alaskan Native	0.000	0.000	0.000	0.000
Pacific Islander or Native Hawaiian	0.000	0.000	0.000	0.000
Multi-racial	0.010	0.000	0.000	0.000
Prefer not to answer	0.020	0.054	0.030	0.010
Income				
<$20,000	0.022	0.047	0.011	0.053
$20,000–$29,999	0.045	0.071	0.067	0.032
$30,000–$39,999	0.056	0.071	0.045	0.085
$40,000–$49,999	0.124*	0.071	0.090	0.043*
$50,000–$74,999	0.315	0.259	0.292	0.255
$75,000–$99,999	0.169*	0.200	0.292*	0.223
$100,000–$149,999	0.191*	0.165	0.090*,**	0.202**
≥$150,000	0.079	0.118	0.112	0.106
Education				
Less than grade 11	0.020	0.055	0.052	0.040
High school or equivalent	0.276*	0.440*	0.340	0.374
Some college	0.306*	0.165*	0.196	0.192
Associate's degree or equivalent	0.184	0.154	0.175	0.172
Bachelor's degree	0.122	0.132	0.196	0.162
Graduate/professional degree	0.092	0.055	0.041	0.061
Observations	101	94	102	102

[a]All figures are proportions unless otherwise noted.
[b]Superscripts * and ** indicate pairs of estimates that are statistically different from one another at the 5% level. For example, the proportion of respondents with income between $100,000 and $149,999 are different for the Bag limit = 1, quota = 300 and Bag limit = 1, quota = 600 treatments (indicated by the * superscript) and for the Bag limit = 1, quota = 600 and Bag limit = 2, quota = 600 treatments (indicated by the ** superscript).

Table 3. Logit model parameter estimates

	Model[a]			
	1	1	1	2
Variable\Sample	Full	Agree	Do not agree	Full
Constant	−0.2817	0.8212	−2.7481***	1.0695***
	(0.4668)	(0.5768)	(0.9390)	(0.3815)
Price	−0.0214**	−0.0252**	−0.0136	−0.0251***
	(0.0086)	(0.0106)	(0.0162)	(0.0091)
Quota	−0.0001	−0.0006	0.0010	—
	(0.0007)	(0.0008)	(0.0014)	
Interacted with:				
Age	—	—	—	−5.7E−5***
				(1.9E−5)
Harvest for income	—	—	—	0.0020*
				(.0011)
College	—	—	—	0.0013
				(0.0010)
Bag limit	0.6052***	0.2260	1.3927***	—
	(0.2053)	(0.2467)	(0.4165)	
Interacted with:				
Age	—	—	—	0.0115**
				(0.0056)
Harvest for income	—	—	—	−0.5487
				(0.3409)
College	—	—	—	−0.2602
				(0.3124)
Observations	399	286	113	340
Log-likelihood	−267.2	−186.9	−68.26	−222.9

[a]Standard errors are in parentheses below each coefficient.

Respondents received a hypothetical bobcat hunting/trapping season description with one of four bag and quota combinations. Proportions of usable surveys received were nearly equal across bag and quota combinations, with 25.3% receiving bag limit = 1 and quota = 300, 25.6% receiving bag limit = 1 and quota = 600, 23.6% receiving bag limit = 2, quota = 300, and 25.6% receiving bag limit = 2 and quota = 600. Table 2 is a balance table that shows respondent demographics by treatment. Pairs of figures marked with common superscripts denote attributes that are statistically different from one another at the 5% level or better. The subsamples are largely similar across treatments.
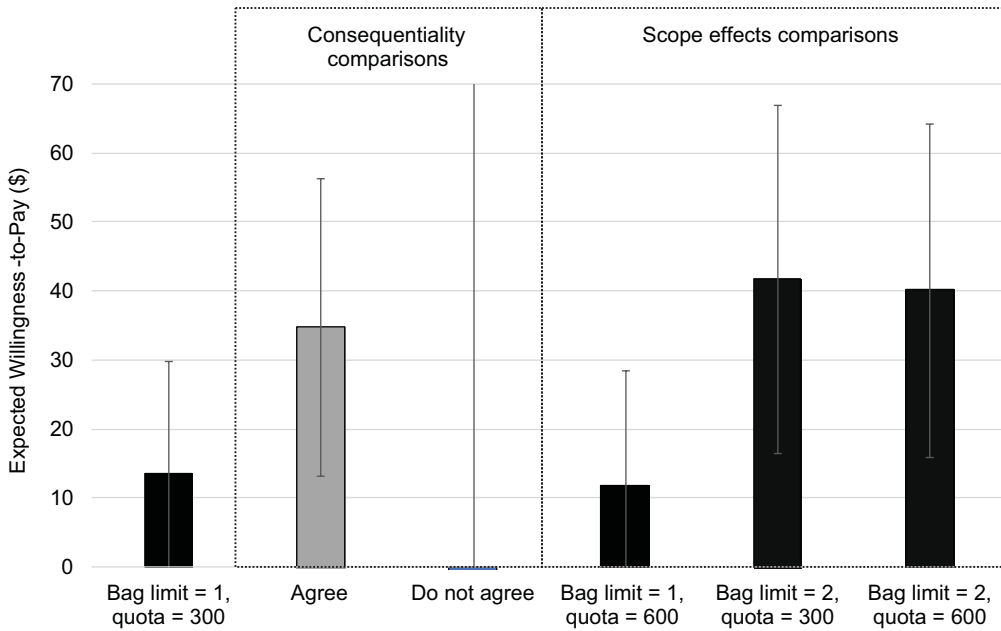
80   Nicholas A. Lancaster et al.

Figure 4. Willingness to pay estimates from the RUM model.

4. Results

The first and last columns in Table 3 show parameter estimates for two specifications of our RUM model. The specifications differ in the combination of sociodemographic characteristics $\mathbf{Z}_i$ included as covariates. Model 1 includes no demographics and assumes respondents' preferences over bobcat permits are homogeneous. Model 2 includes age, education, and a dummy variable equal to one if the respondent reported harvesting furbearers to sell for income. Our hypothesis is that respondents with potential financial motivations for harvesting bobcats may have a different objective function than those who only harvest furbearers recreationally. We represent education as a dummy variable equal to one if the respondent has attended college and zero otherwise.

The estimated coefficients on price are negative, statistically significant at the five percent level or better, and are of similar magnitudes across models. In Model 1, we find utility increases with the bag limit, whereas increasing the quota has no statistically significant effect. Interpretation of the coefficients in other models is not straightforward due to the interactions between covariates.

To assess fit, we estimated each model using only the respondents for which we observe all covariates included in Model 2 and calculate the corresponding Akaike and Bayesian Information Criteria. We find that Model 1 fits the data best, and hence we use these estimates in calculating WTP.

Figure 4 shows WTP estimates for our RUM model. We calculate 95% confidence intervals using the delta method. The first bar shows WTP for the baseline bobcat permit (i.e., a bag limit of one and a statewide quota of 300) among all respondents, regardless of their answers to the consequentiality questions in Fig. 3. Mean WTP is $13.50, although this estimate is not statistically significantly different from zero ($p = 0.106$).

As a robustness check, we also estimate WTP using a nonparametric Turnbull estimator. For conciseness, we describe this estimator and present results in Appendix B. Mean WTP under the Turnbull estimator is $21.73.

4.1. Consequentiality

We performed two tests of the validity of this baseline estimate. The first assesses consequentiality among our respondents. Specifically, we compare our baseline WTP estimate to that estimated from subsamples of respondents comprising (i) only those who agreed to at least one of the three consequentiality statements in Fig. 3 and (ii) those who did not agree to any of the consequentiality statements. We consider a respondent to have agreed with a consequentiality statement if they indicated that they "Somewhat Agree" or "Strongly Agree." This comparison provides insight into how seriously participants believe their responses will impact the creation of a bobcat season at the price they received. We anticipate those with nonconsequential responses will have a different and potentially nonsensical distribution of WTP than those with consequential beliefs (Herriges et al., 2010; Interis and Petrolia, 2014). Roughly two-thirds of respondents who saw the baseline permit agreed with the consequentiality statements. The second column of Table 3 shows parameter estimates for this model, and we find mean WTP among those respondents to be $34.85 (see the bars labeled "consequentiality comparisons" in Fig. 4). This estimate is statistically significant. In contrast, mean WTP is actually negative among those who do not agree with the consequentiality statements. The 95% confidence interval is large and includes zero. Our Turnbull estimates presented in the appendix find a similar decrease in mean WTP, and the difference in WTP between those who do and do not find the survey consequential is statistically significant.

4.2. Scope effects

From (5), scope effects of changing the quota and bag limit will depend on the signs of $\boldsymbol{\beta}_i$, which depends on two terms (see (4b)). The first, $(\partial U_i/\partial H_i)(\partial H_i/\partial x_j)$, we call the "direct" scope effect from changing attribute j. This term measures the *ceteris paribus* effect of changing the quota or bag limit on harvest and, hence, utility, since $\partial U_i/\partial H_i > 0$ by assumption. The second term, $(\partial U_i/\partial H_i)(\partial H_i/\partial n)(\partial n/\partial x_j)$, is the "congestion" scope effect from changing attribute j. Intuitively, changing the permit attributes may affect the number of hunters who purchase a permit and attempt to harvest bobcats, n. Since $\partial H_i/\partial n < 0$ by assumption, a positive value for $\partial n/\partial x_j$ will generate greater competition for harvests, reducing harvests and, hence, welfare for the representative hunter.

Consider first the quota effect β_{i1} reported in the first column of Table 3. We would expect the direct effect to be positive; increasing the quota while holding bag limits fixed increases the probability an individual hunter can fill his or her bag limit before the aggregate quota is met. The congestion effect is negative, however, as $\partial n/\partial x_1 > 0$ given the logistic distribution for the ε terms and $\partial H/\partial n \leq 0$. Hence, the congestion effect attenuates the direct effect of increasing the quota. This is consistent with our estimates, which show no statistically significant scope effects from changing the quota across any of the models.

Consider next the effect of the bag limit β_{i2} reported in the first column of Table 3. The scope effects from changing the bag limit are ambiguous given our lack of intuition about the sign of $\partial H/\partial x_2$. If $\partial H/\partial x_2 > 0$, then the direct effect of changing the bag limit will be positive, but the congestion effect will attenuate the scope effect, as above. If $\partial H/\partial x_2 < 0$, then the direct effect is negative but the congestion effect is positive; increasing the bag limit will reduce WTP due to increased competition given the fixed quota, but this will reduce permit demand (i.e., n will decline), attenuating the negative direct effect. We find mixed evidence of this effect in our logit and Turnbull estimates.

Estimates of WTP for different combinations of the bobcat bag limit and statewide quotas are labeled "scope effects comparisons" in Fig. 4. Increasing the quota has a negative but statistically indiscernible effect on WTP, consistent with the negative but statistically insignificant coefficient on quota shown in the first column of Table 3. Increasing the bag limit has a large and positive effect on mean WTP regardless of the quota. The nonparametric Turnbull estimates in the appendix reveal slightly different scope effects; increasing the bag limit while holding the quota fixed at 300 decreases WTP, whereas increasing the quota while holding the bag limit fixed at two

increases WTP (although neither of these differences is statistically significant.) Taken together, we find no systematic relationship between WTP and the quantity respondents are allowed to harvest either individually or in aggregate. This is consistent with our theoretical results showing that we may expect variable scope effects in permit demand.

5. Discussion and conclusion

Wildlife managers are facing declines in hunting participation across the U.S. (Enck et al., 1996, 2000; Mehmood et al., 2003; Miller and Vaske, 2003; US DOI et al., 2016; US DOI et al., 2011). While permit fees have historically been kept low, with marginal fee increases disproportionately low in relation to changes in the cost of living (Sutton et al., 2001), reduced hunting participation forces wildlife managers to increase permit prices or create new permits in order to maintain funding for wildlife management (Brunke et al., 2006). Research has confirmed a significant inverse relationship between permit fees and the number of permits purchased (Brunke et al., 2006). Therefore, regulators must exercise caution when setting permit fees. This paper shines new light on the relationship between permit fees and demand by measuring hunters' WTP for a new permit. Because bobcats currently have no hunting or trapping season in Indiana, we cannot measure the effect of price on demand using historic permit sales data. Furthermore, we cannot estimate WTP using revealed preference valuation methods that rely on observing individual decisions to purchase a good or undertake an activity; there simply are no such data as bobcat harvest is not allowed. Hence, we must use stated preference methods – which draw on individuals' choices in hypothetical scenarios – to estimate WTP for bobcat permits. We use CVM, under which individuals are asked whether they would be willing to pay an experimentally generated price to acquire the scenario or good (Sorg and Loomis, 1985). Responses to these questions can be used to estimate the number of individuals who would make the purchase at any given price (Brookshire et al., 1980).

CVM, like other stated preference methods, is flexible but may be subject to biases, including strategic behavior, information bias, and instrument biases (Schulze et al., 1981). The presence of bias is due to the reliance of CVM upon an individual's response to a hypothetical market (Stoll, 1983). In a recent meta-analysis, Penn and Hu (2018) found that this hypothetical bias can inflate measures of WTP by nearly 200% relative to their true values, although the use of questions that assess consequentiality (like we include in our questionnaire; Fig. 3) can mitigate this bias.

Tests of consequentiality and scope effects can also provide evidence of the validity of CVM estimates. Indeed, consequentiality has been deemed necessary to ensure incentive compatibility and is broadly defined as the belief that the respondent's choice will influence policy with a non-zero probability (Carson et al., 2014; Herriges et al., 2010; Vossler et al., 2012). Herriges et al. (2010) find that respondents who perceived a survey as inconsequential had a lower WTP than those who perceived the survey to be at least slightly consequential in the creation of the policy. Similarly, our test of consequentiality reveals a significant change in the distribution of WTP for those who do not believe their answers will affect bobcat management policy.

Reduced perception of consequentiality among respondents may be linked to the level of trust placed in the regulatory agency. Distrust in regulatory agencies' ability to effectively manage wildlife and the resulting destructive behavior of hunters is well-documented in the literature. Illegal harvests of wolves in Denmark have been linked to distrust of authorities setting regulations to mitigate the negative impacts of wolves (Højberg et al., 2017). Muth and Bowe's (2008) review on illegal harvests in North America revealed that disagreement with regulations was one of the top drivers of poaching. While our survey does not touch upon the subject of poaching, we propose that finding diminished or zero WTP for an economically important species could be linked to regulator trust. Distrust in a regulatory agency may originate from differing ideals. Gigliotti et al. (2020) showed that trust in the Minnesota Department of Natural Resources was tied to landowners' beliefs, with landowners holding similar conservation values, placing greater

trust in the regulatory agency. Similarly, Manfredo et al. (2017) surveyed residents across the United States and found that residents with conservation principles similar to regulatory agencies were more likely to place trust in the regulator relative to those who are skeptical of government regulation of wildlife. Likewise, a 2021 survey of Indiana residents regarding deer management showed level of trust in the manager is predominantly linked to respondents' characteristics (Stinchcomb et al., 2022). Possibly, lower WTP among the individuals who did not perceive our survey as consequential could be due to beliefs that governance of wildlife is undesirable.

We found mixed evidence of scope effects. This could be due to countervailing indirect effects in equilibrium. Evaluating scope effects in the context of rationed goods like bobcat harvest permits is not theoretically straightforward, as we demonstrate here. That aggregate harvests are fixed at a given quota level implies hunters' expected harvests will depend on the number of hunters who purchase a permit and compete to fill their bag limit. Since we expect hunter utility – and hence the share of potential hunters that purchase a permit – is increasing in expected harvest, the number of hunters and expected harvest are determined endogenously as a function of the bag limit and quota. To the extent that these permit attributes have different *ceteris paribus* impacts on expected harvest, then increasing either the bag limit or quota may systematically affect equilibrium participation – and hence expected harvest and WTP – in different and countervailing ways. Discerning which attribute is most relevant for testing scope effects in the context of rationed goods is important for demonstrating the validity of WTP estimates; however, to our knowledge, no prior work addresses this issue. We leave a more rigorous study of this question for future research. Finally, there are some counterintuitive and inconsistent scope effects when comparing the logit estimates with the Turnbull estimates in the appendix. One possible explanation is that our data are simply noisy. Another explanation is that differences are due to the relative flexibility of the Turnbull model, which imposes no distributional assumptions on WTP.

Indiana is among seven U.S. states that have bobcat populations but do not have open regulated hunting or trapping seasons for bobcats. Our WTP estimate can provide information to these jurisdictions should they consider a regulated season, allowing them to have some baseline information on how to price a stand-alone bobcat license. For states that allow the take of bobcats on existing hunting or trapping licenses, it can aid agencies in justifying license price increases by understanding the value-added of expanding a license to include bobcats.

More broadly, this paper demonstrates a methodology that state agencies can use to set license prices as they have additional species for which they are considering new harvest opportunities. Many states are seeing population expansions for wildlife, whether due to climate change (Thomas, 2010), species recovery (e.g., LaRue et al., 2012; Roberts and Crimmins, 2010), or reintroduction programs (e.g., Bricker et al., 2022; Popp et al., 2014). For some species, that leads to considerations of limited, regulated seasons, such as in 2021 when Missouri opened its first regulated black bear season or Nebraska opened its first regulated river otter season. Because a basic tenant of wildlife management is to work to ensure that most individuals have equitable access to hunting and fishing opportunities (Geist et al., 2001), state agencies have a responsibility to ensure hunting opportunities do not become a highly desired but prohibitively expensive good. Having a viable technique to calculate WTP or having examples of WTP for certain species in the literature ensures state agencies have information to set pricing that finds a reasonable balance between cost and ensuring access to those who want to participate across income levels.

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