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Quality of Life as an Explanation of the Divergence between Ranchers' WTA and WTP for Public Forage

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Abstract

The research reported here provides further empirical support for the contention that there is a divergence between WTA and WTP. The conclusion is based on results from a 2002 survey of Nevada ranchers that asked about willingness to pay for public forage and willingness to accept compensation to part with grazing rights. WTP and WTA are estimated simultaneously, with the estimators used to demonstrate a statistically significant divergence between WTP and WTA. The simultaneous estimation enables the identification of ranch characteristics that influence the discrepancy in valuations. Ranch size, public grazing allotment, financial distress, and long-term commitment to ranching are all significant influences on the disparity. We interpret these results both with respect to general differences in welfare measures and with respect to ranch policy, concluding that the ranching lifestyle accounts for some of the difference between WTP and WTA for public forage.

JEL Classification Numbers: Q15, Q24, Q51.

Keywords: quality of life and ranching; divergence between WTA and WTP; grazing rights and public forage

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1. Introduction

When people are asked to value changes in the availability of a public or environmental good, willingness to accept compensation (hereafter WTA) generally exceeds willingness to pay (WTP), often by a substantial amount. Hanemann (1991), building on earlier work by Randall and Stoll (1980), demonstrates that divergence between WTA and WTP is to be expected for many environmental goods. Specifically, public goods that have few if any private goods that are ready substitutes, which may be the case for environmental goods, are likely to have WTA valuations in excess of WTP valuations.[1]

Alternatively, evidence from contingent valuation surveys and experimental markets suggests that individuals become attached to a particular endowment, requiring a higher level of compensation to part with something than they would pay to obtain it (Knetsch 1995). The problem is not on the supply side (availability of substitutes), but lies with preferences. Indifference curves are somehow kinked (and not continuously differentiable) at the endowment. Thus, the observed difference between WTP and WTA remains, even for market goods where there are adequate substitutes, such as mugs and candy bars.[2]

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[1] Divergence in the welfare measures is also positively related to the income elasticity of demand for the good in question, though Hanemann argues the substitute effects are likely to be more important. More generally, the income effect is usually regarded to be insufficient to explain the observed divergences in valuations; see Hanemann (1991) and references cited therein.

[2] Empirical support for the endowment effect is presented in Kahneman, Knetsch and Thaler (1990) and Knetsch, Tang and Thaler (2001). Shogren et al. (1994) and List (2003, 2004) present evidence against the endowment effect; Shogren et al. use experimental data to demonstrate that, for goods for which substitutes are plentiful, WTP and WTA converge with repeated market participation, but for goods with few substitutes repeated participation did not result in convergence; List finds that the endowment effect is prevalent among inexperienced traders, but not among experienced ones (in his

Whatever the explanation, the disparity between the two valuation measures is well established theoretically and empirically, with the empirical evidence nicely summarized in Horowitz and McConnell (2002). The objective of this paper is to examine this disparity in further detail in the context of a recent survey of Nevada ranchers that concerned access to grazing on public lands. The survey elicits both a willingness to pay and a willingness to accept valuation for public forage; in addition it provides a rich set of information about ranch characteristics. The dual nature of the survey, both WTP and WTA, and the extensive information set on ranch characteristics allows us to examine the disparity between welfare measures in a systematic manner. We use a bivariate dichotomous choice framework to model the willingness to pay and accept decisions simultaneously, similar to Poe, Welsh and Champ (1997). This framework allows us to test directly the difference in welfare measures, and examine whether quality of life is a contributing factor to the observed differences in welfare measures, as asserted by range economists (Torell et al. 2006).

To foreshadow our principal results, we find a significant disparity between willingness to accept and willingness to pay valuations. The discrepancy between valuations is similar to previous studies, with WTA ranging from 2-12 times as large as WTP. We find a number of ranch characteristics associated with this discrepancy: (1) the size of the ranch, which we conjecture may relate to available substitutes for public grazing; (2) the size of allocation of public grazing, which is surprisingly inversely related to the discrepancy in valuations; (3) financial distress; and (4) long-term commitment to ranching as a lifestyle. Each of these results bears on public grazing policy.

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case, trading sport memorabilia). Whether these results refute endowment effects is a matter of some debate; see Knetsch, Tang and Thaler (2001) and Donkers, Gregory and Knetsch (2004).

The remainder of the paper is organized as follows. In the next section, we provide a brief background to the issue of livestock grazing on public lands, and we provide a brief description of the 2002 Nevada Ranch Survey. The theoretical model is provided in section 3, while the WTA and WTP estimation results are provided in section 4. We conclude in section 5 with a discussion of policy implications and considerations for further research.

2. Grazing on Public Range and the Nevada Ranch Survey

Although open access grazing ended on some public lands around 1900, it was not until the Taylor Grazing Act of 1934 that it was halted on all public lands in the United States. Over the three decades that followed, administration of grazing on public lands evolved into a system characterized by grazing districts and allotments, limits on herd size (effectively limiting the size of ranches), and fees for public forage using the animal unit month (AUM) measure.[3] While grazing fees differed on U.S. Forest Service and Bureau of Land Management (BLM) lands until 1981, the 1978 Public Rangelands Improvement Act established that all grazing fees would be calculated as a base fee of $1.23 per AUM (established in 1966 using a cost of production approach) that was adjusted using indexes of private grazing values, livestock market prices and rancher operating costs, but with the proviso that the fee not decline below $1.35 per AUM.[4]

The grazing fee reached a high of $2.36 per AUM in 1980 falling to $1.35 in 1985, never again to exceed $2 per AUM; the grazing fee was $1.43 in 2002, falling back to $1.35 in 2003 where it had been for most of the previous decade. This despite the fact that cattle

[3] An AUM is the amount of forage needed to support one cow and calf, one horse or five sheep for a period of one month.
[4] See Torell et al. (2001) and Dietz and Rothenberg (2000).

have generally increased in size and private alternatives for grazing averaged $11 per AUM in 1997 (Diez and Rothenberg 2000). In Oregon, private grazing was valued at an average of $9.23 per AUM in 2004, and an average $8.83 per AUM in the two most southeasterly counties in the State, Malheur ($2.53 per AUM) and Harney ($12.43 per AUM) counties, which border Nevada.[5] In 2003, while the BLM grazing fee was set at $1.35, the respective fees charged on state-owned lands in Oregon, Idaho and Washington were $4.16, $5.33 and $7.52 per AUM.[6]

Although rates of return to livestock production average no more than 2 percent while the return to private grazing lands is estimated to average 3.4 percent (Bartlett et al. 2002), grazing permits that give ranchers perpetual rights to graze cattle on public land have positive value.[7] In theory, the value of a grazing permit is equal to the difference between the marginal value of public forage minus the grazing fee appropriately discounted, where the discount rate takes into account the possibility of losing the right to graze livestock at some future time (Gardner 1962, 1963). Grazing permits are generally not traded, although they do get capitalized in ranch values, so it is difficult to determine their true value. However, research by Borges and Knetsch (1998) does suggest one reason why little trading of grazing permits occurs, namely, that those holding permits value them more highly than those

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[5] U.S. Department of Agriculture data for 2004 reported by Barry Adam and viewed 1 June 2004 at www.oregonstatelands.us/rangeland_audit_response.pdf. The disparity between costs of private forage in these counties is surprising. Data for Lake County (the county to the immediate west of Harney) were not available for reasons of confidentiality.

[6] Same source as in previous note.

[7] Grazing permits are considered a privilege and not a right. On May 15, 2000, the U.S. Supreme Court ruled in a unanimous decision that the appeal by the Public Lands Council et al. in opposition to Bruce Babbitt, Secretary of the Interior et al. and the Range Reform Regulations of 1995, has no legal basis. The Court rejected all the arguments that ranchers on public lands have a vested grazing right. See w3.trib.com/~phxcon/supcourtgraz1.html. Politicians have, however, acted as if the permits are a right.

wanting to buy them.

Range economists argue that private and public grazing values are not directly comparable, because operating costs are higher on public lands and private landowners provide services (not available from federal land agencies) that account for at least 30 percent of private value (Bartlett et al. 2002, p.429; Gardner 1962, p.53). Suppose private grazing sells for $9.23/AUM (the average for Oregon), while the BLM charges $1.35 per AUM. Then the benefit from public forage is $5.11 per AUM (=0.7×$9.23–$1.35) and, using the perpetual bond formula (bond value = annual payment ÷ r, where r is the discount rate), a grazing permit would be worth about $128 per AUM if a discount rate of 4% is used (≈$5.11/0.04) and $255 if a rate of 2% is used.

Ranchers' use of public lands has increasingly come under pressure from environmental groups that see livestock grazing as a contributing factor to the environmental degradation of public lands, and particularly loss of wildlife habitat. The public land agencies have reacted primarily by reducing grazing services. In Nevada, for example, AUMs of grazing have fallen by 32.7% (or some 540,000 AUMs) between 1981 and 2002, threatening the viability of some ranchers dependant upon public forage. To address the external impacts of livestock grazing on public lands while making reductions in AUMs politically palatable, Congress has recently begun to consider purchasing ranchers' grazing permits. Section 5(a) of the Voluntary Grazing Permit Buyout Act (Bill HR 3324 IH) introduced into the Congress on 16 October 2003 (108th Congress, 1st Session), for example, would have compensated ranchers $175 per AUM, an amount well within the range calculated above.

Sale of grazing permits implies irrevocable loss of access to the public range and, in most cases, loss of a particular lifestyle. Range economists argue that, because rates of return

to livestock production average no more than 2%, grazing permits have value only because they provide the owner with a quality of life benefit (Bartlett et al. 2002; Torell et al. 2005). That is, there is no evidence that public land ranchers are subsidized and make an inflated rate of return because of low grazing fees (Torell et al. 2001 p.6), so the value of grazing permits is equivalent to the value placed on the ranching lifestyle. Even if this is true, simple neoclassical theory indicates that ranchers should be WTP as much to purchase public forage in a world where available AUMs are declining as they would be WTA to forgo public forage forever – they should be willing to pay as much to keep the lifestyle as they would be willing to accept to forgo it.

To investigate the relationship between these welfare measures, we use the 2002 Nevada Ranch Survey, which elicited WTA and WTP responses for public grazing. It also included questions dealing with the ranch operation, community activities, experience with fire, investments in range improvements, attitudes toward the public land agencies and the future of public land-based ranching, income, education, and so on. The context of the survey was the reduction in AUMs of public grazing to protect environmental amenities (noted above). Ranchers were asked about their WTP for access to public forage and their WTA compensation for sale of grazing privileges. These questions were embedded in the survey and required a 'yes'/'no' response to a proposed 'bid'. There were 244 usable surveys after taking into account non-respondents and those who did not complete some parts of the survey needed for the current analysis. More information on the survey design, response rates and descriptive variables can be found in Thomsen (2002), van Kooten, Thomsen and Hobby (2006), and van Kooten et al. (2006).

3. Empirical Model

Ranchers are asked both a willingness to pay and a willingness to accept question in the same survey. As the responses are likely related, we use a systems based approach to estimation, similar to that used by Poe, Welsh and Champ (1997) and Cameron and Quiggin (1994). Our objective is to test whether there is a divergence between WTA and WTP and to determine the factors explaining the divergence, if any.

The *i*th rancher is given randomly determined posted prices for access to grazing rights on public land. In the first instance, the question is structured in terms of willingness to accept a one time payment per AUM for loss of access to public grazing rights. The posted price is denoted p_{1i} and ranchers either indicates they accept the price, y_{1i}=1, or they reject the price, y_{1i}=0. The next posted price is structured in terms of willingness to pay per AUM for access to public grazing rights.[8] The posted price is denoted p_{2i} and the ranchers either indicate they are willing to accept the price, y_{2i}=1, or they reject the price, y_{2i}=0. In addition to the questions concerning willingness to accept and to pay posted offers, the survey asks a number of questions about ranchers' individual characteristics; these covariates are denoted $\mathbf{x}_i$.

Notice that the nature of the questions asked mean that the WTP and WTA questions are not eliciting immediately comparable information. The WTP is in terms of an annual payment while the WTA is in terms of a current valued one off payment. This requires some adjustment for the different time-value, a point to which we return below.

To model individual decisions in our survey, we use the random utility framework for

[8] Although not explicit in the survey question (see appendix to this chapter), the context is clearly that of an annual payment for one month worth of public forage – a quantity measure.

discrete response models discussed in Hanemann (1984). Each rancher i is assumed to have some true unobservable surplus value v_{ji} for each scenario presented in the survey. Here as above, $j = 1$ refers to the willingness to accept scenario while $j = 2$ refers to the willingness to pay scenario. The surplus in each case is assumed to depend linearly upon a vector of observable attributes $\mathbf{x}_i$, the relevant posted prices p_{ji}, and a random component ε_{ji}:

$$v_{ji} = \beta_j' \mathbf{x}_i + \gamma_j p_{ji} + \varepsilon_{ji}.$$

The errors are assumed to be jointly standard normal with covariance (equivalently correlation) ρ; further, the errors are independent of $\mathbf{x}_i$.[9] The covariates are assumed to be common across both surplus measures though we do allow for differing slope coefficients. To fix ideas, we expect that, as offers to forgo public grazing increase, p_{1i} rises, the surplus to rancher i will increase, so $\gamma_1 > 0$. Similarly, as suggested payments for public grazing increase, p_{2i} rises, the surplus to rancher i will decrease, so $\gamma_2 < 0$.

To estimate the model, we proceed as follows. Denote the bivariate standard normal cumulative density function as $\Phi_2(z_1, z_2; \rho)$. Let $z_{ji} = \beta_j' \mathbf{x}_i + \gamma_j p_{ji}$, for $j = 1, 2$. Then the following describes the possible outcomes associated with our model; consider first the case of both the WTP and WTA offered being accepted by individual i:

$$\begin{aligned}\text{Prob}(Y_1 = 1, Y_2 = 1 | \mathbf{x}_i) &= \text{Prob}(z_{1i} + \varepsilon_{1i} \geq 0, z_{2i} + \varepsilon_{2i} \geq 0 | \mathbf{x}_i) \\ &= \text{Prob}(\varepsilon_{1i} \leq z_{1i}, \varepsilon_{2i} \leq z_{2i} | \mathbf{x}_i) \\ &= \Phi_2(z_{1i}, z_{2i}; \rho)\end{aligned}$$

where the second last line makes use of the symmetry of the bivariate normal distribution. By

[9] The assumption of normality for the error terms allows for straightforward estimation; the common alternative, the logistic distribution, is not suitable for these purposes, see Cameron and Quiggin (1994). The unit variance is a simplifying assumption that does not affect our analysis.

similar reasoning we get the remaining outcomes:

$$\text{Prob}(Y_1 = 1,\ Y_2 = 0 \mid \mathbf{x}_i) = \Phi_2(z_{1i}, -z_{2i}; \rho)$$

$$\text{Prob}(Y_1 = 0,\ Y_2 = 1 \mid \mathbf{x}_i) = \Phi_2(-z_{1i}, z_{2i}; \rho)$$

$$\text{Prob}(Y_1 = 0,\ Y_2 = 0 \mid \mathbf{x}_i) = \Phi_2(-z_{1i}, -z_{2i}; \rho)$$

The log-likelihood for the data is then,

$$\ln L = \sum_{i=1}^{N}((y_{1i}y_{2i})\ln\Phi_2(z_{1i}, z_{2i}; \rho) + (y_{1i})(1-y_{2i})\ln\Phi_2(z_{1i}, -z_{2i}; \rho) + (1-y_{1i})(y_{2i})\ln\Phi_2(-z_{1i}, z_{2i}; \rho) + (1-y_{1i})(1-y_{2i})\ln\Phi_2(-z_{1i}, -z_{2i}; \rho))$$

The model parameters, including ρ, are estimated using standard maximum likelihood methods, see Greene (2002). We can also test the bivariate model against the simpler set up of two univariate models by testing the null hypothesis of $\rho = 0$. Both the univariate models and the bivariate model provide consistent estimates of the model parameters; however, if $\rho \neq 0$, then the bivariate model is more efficient (Poe, Welsh and Champ 1997). In what follows, we report both univariate and bivariate results as well as a likelihood ratio test of $\rho = 0$.

With the model estimated, we can calculate measures of willingness to pay and to accept and investigate what might explain any observed differences. The linear expression for the surplus value is consistent with an underlying indirect utility function that is linear in the dichotomous variable indicating access to public grazing or not, income, and other covariates. The linear indirect utility function means that the welfare measures of interest are simple linear functions of the estimated model parameters and covariates (Hanemann 1984).

Let WTA_i denote the individual's willingness to accept and WTP_i denote the individual's willingness to pay. Then define $\tilde{p}_{1i}$ as the expectation, conditional on $\mathbf{x}_i$, of the individual's willingness to accept and $\tilde{p}_{2i}$ as the expectation, conditional on $\mathbf{x}_i$, of the individual's willingness to pay. Equivalently in our linear environment these are individual's

median willingness to accept or to pay; that is, posted offers at which there is a fifty percent probability the individual rancher will accept the offer. This is easily calculated as the value of p_{ji} that sets the non-random component of the surplus measure to zero:

$$\tilde{p}_{1i} \equiv E(WTA_i \mid \mathbf{x}_i) = -\frac{1}{\gamma_1}\beta_1^{'}\ \mathbf{x}_i$$

$$\tilde{p}_{2i} \equiv E(WTA_i \mid \mathbf{x}_i) = -\frac{1}{\gamma_2}\beta_2^{'}\ \mathbf{x}_i$$

where the expectation is taken over the marginal distribution of ε_{1i} in the first equation and ε_{2i} in the second equation. Taking expectations over the sample with $\mathbf{x}_i$ respect to the random covariates gives the standard measures of mean WTP and WTA:

$$\overline{WTA} = -\frac{1}{\gamma_1}\beta_1^{'}\,\overline{\mathrm{x}}$$

$$\overline{WTP} = -\frac{1}{\gamma_2}\beta_2^{'}\,\overline{\mathrm{x}}$$

Estimates of either individual or sample contingent valuations are obtained by substituting the ML parameter estimates, denoted $\hat{\gamma}_j$ and $\hat{\beta}_j$. In this study, we focus on the sample measures.

Estimates of mean WTP and WTA provide information concerning the relationship between these variables and the covariates used in estimation, which is one area of interest. We are primarily interested in the differences between willingness to pay and to accept, however, and how these might be explained by the covariates. To explore this, we need first to make the two measures comparable, as one is in terms of a flow (willingness to pay) while the other is in terms of a stock (willingness to accept). If we assume that all ranchers have the same discount rate r, then our hypothesis is:

$$\overline{WTP}/r = \overline{WTA}$$

where we have interpreted the WTP payment as a perpetual flow. In terms of the model parameters, this is

$$H_0\text{: } \frac{1}{\gamma_1}\beta_1^{'}\,\overline{\mathrm{x}} - \frac{1}{\gamma_2}\beta_2^{'}\,\overline{\mathrm{x}}\,/\,r = 0$$

where we now let $\overline{\mathrm{x}} = \frac{1}{N}\sum_{\mathrm{i}} \mathbf{x}_{\mathrm{i}}$. This hypothesis can be tested using a standard Wald test.[10]

The next issue is to consider what factors (which of the attributes $\mathbf{x}_{\mathrm{i}}$) systematically contribute to the divergence between our measure of willingness to pay and to accept. For any individual *i* we can again write,

$$\tilde{p}_{1i} - r\tilde{p}_{2i} = -\frac{1}{\gamma_1}\beta_1^{'}\mathbf{x}_{\mathrm{i}} + \frac{1}{\gamma_2}\beta_2^{'}\mathbf{x}_{\mathrm{i}}/r = (\frac{1}{\gamma_2}\beta_2^{'}/r - \frac{1}{\gamma_1}\beta_1^{'})\,\mathbf{x}_{\mathrm{i}}$$

For any covariate *k*, we can define the contribution to the difference as $(\frac{\beta_{2k}}{r\gamma_2} - \frac{\beta_{1k}}{\gamma_1})x_{ik}$ and test the hypothesis, for each *k* and conditional on *r*:

$$H_0\text{: } (\frac{\beta_{2k}}{r\gamma_2} - \frac{\beta_{1k}}{\gamma_1}) = 0$$

4. Empirical Results

The Data

A summary of the posted offers and frequencies of discrete responses is provided in Table 1. Of the 244 usable returned surveys, we consider 194 responses that provide a

[10] The Wald test we construct is based upon a delta method approximation, which may not be ideal. An alternative is to use bootstrap methods to estimate the distribution of the individual or across sample valuation measures (see Poe, Welsh and Champ 1997), but we leave this for future work.

complete set of responses to the conditioning variables of interest (these are discussed further below). As evident from the table, the majority of respondents rejected both willingness to pay and the willingness to accept posted offers. Just under ten percent accepted one but not the other offer and only one percent accepted both, suggesting that on balance the survey offers were likely set too low or too high. Yet, despite this, the results indicate that there is sufficient variation to enable us to make statistically significant conclusions concerning the valuation measures of interest.

The survey asked respondents to provide a wide variety of information beyond their willingness to pay or accept the posted offer. Due to the nature of the estimation, however, we found it necessary to select a relatively small subset of the possible conditioning variables. We chose those that we thought most likely to have some information concerning the differences in welfare measures; these variables are described in Table 2. For purposes of later discussion, the variables are grouped into (i) financial factors, including income, and education, (ii) lifestyle or quality of life factors, and (iii) attitudes towards environment.

In the first grouping, we have income by category (income from all sources and not only ranching), acres owned by the rancher, acres of public grazing currently used, an indicator of financial stress (Likert scale), and education by category. For the second group, we are looking for variables that suggest a strong attachment to ranching and the local community as indicators of how important the ranching lifestyle is to the respondent. We conjecture that the greater the attachment the greater any endowment effect is likely to be. The variables we select for this are whether the rancher works off the ranch, whether the rancher intends to bequeath the ranch, and whether they are participants in community events such as local sports. Finally, the third grouping consists of an indicator of whether the

rancher views grazing as a threat to endangered wildlife. As the issue of public grazing rights is closely linked to environmental concerns, this is a natural direction to explore.

Based on these variables, a typical ranch owner has a 10,000 acre ranch, uses roughly 6,000 AUMs of public forage, earns between $60-75000, considers herself to be under financial stress from the livestock business, has attended or completed college, plans to pass the ranch on to their heir(s), and does not believe that ranching threatens wildlife. Working part time appears not to be an option, with ranchers either working full time on the ranch or full time elsewhere. This latter characteristic suggests that just under half of the respondents are hobby ranchers (i.e., 45% of ranchers work full time off the ranch). Finally, a slight majority of ranchers do not regularly participate in community events, such as local sporting events.[11]

Probit Models

Empirical estimates of general unrestricted bivariate and univariate probit models are provided in Table 3; Table 4 presents more parsimonious versions of these models. In all cases, the models have as dependent variables the posted offers (p_{ji}, j = 1, 2) as well as the covariates, or a subset, discussed above. Note that we also include an interaction term for public grazing and private land ownership to model interdependencies between public and private land uses. Throughout, we restrict the set of covariates to be the same in both the willingness to accept and willingness to pay equations.

Some common features are immediately apparent from the two tables. First, in all cases the posted offers are statistically significant and correctly signed: for willingness to

[11] Details about the exact nature of the survey questions are available in Thomsen (2002).

accept, as the offer rises the probability of acceptance increases; for willingness to pay, as the offer rises the probability of acceptance decreases. The magnitude of the coefficients across the two welfare measures differs but this is to be expected given that the willingness to accept question is phrased in terms of a one-off payment (a large current value number), while the willingness to pay is phrased in terms of a stream of smaller annual payments.

Second, in almost all instances the remaining covariates are statistically significant, if at all, only in the willingness to accept equations. The one exception is a variable concerning ranchers' attitudes toward the local environment. This is somewhat of a puzzle; even if there are good reasons to expect the two welfare measures to differ it is not obvious that they should differ in terms of conditioning variables to this extent. As this is not directly relevant to our main focus, we do not pursue this any further leaving it for further research.

Finally, the two estimation methods provide very similar results in terms of what variables are statistically significant and the coefficient magnitudes, suggesting that the results and any conclusions are robust to these different strategies. Since the correlation coefficient between the disturbances is statistically different from zero and relatively large, and because we wish to consider formal hypothesis tests across the two equations, we focus our discussion on the results of the bivariate probit model. This has the additional advantage of being a more efficient estimator given that $\rho \neq 0$.

The general models in Table 3 identify two variables that are statistically insignificant at the ten percent level, education and whether the respondent works off the ranch or not. The parsimonious models in Table 4 drop these two variables and the bivariate version of this model is our preferred specification. Setting aside for the moment the valuations implicit in the model, we first consider the covariates themselves and how they affect the likelihood of

accepting the posted offers. With the exception of the environmental variable, we can confine the discussion to the willingness to accept equation since the other covariates are statistically insignificant in the willingness to pay equation.

Beginning with household income, we see that the higher a rancher's income category the less likely they are to accept an offer to forgo public grazing land. As this relates to income from all sources, it is not possible directly to link this to the success of the ranching operation.[12] One interpretation is that better off households are best placed to enjoy the benefits of ranching (through a combination of ranch and outside income), and hence are less willing to give up ranching and the associated use of public grazing.

A closely related variable is the extent to which ranchers feel themselves to be under financial stress from the livestock business. The results indicate that the greater the financial stress, the less likely the posted offer is accepted. Plausibly, ranchers under financial stress view the public grazing system as a necessary subsidy to continue ranching and consequently are unwilling to forgo the subsidy. This suggests that the posted offers are not high enough to compensate for the implicit subsidy, a fact that is indirectly supported by the low number of offers accepted across the sample (see Table 1).[13]

The scale of the ranch measured by acres owned also enters with a negative coefficient, indicating that those with larger ranches are less likely to accept an offer to forgo grazing rights. This suggests that the larger ranches are those more dependent upon public

[12] Fifty-four respondents indicated that at least one spouse worked off-farm part time, while in 51 households one worked full time. For these households, an average 75.6% of income was off farm. For all ranches, one-third of income came from off-farm work. Interestingly, there is essentially zero correlation between household income and extent of financial stress from the livestock business.

[13] The buy-out offers used in the survey were based on proposed purchase offers by government and environmental groups, and validated during survey pre-testing. Nor are these amounts excessive based on values considered by range economists (e.g., Torell et al. 2005).

grazing. An implication from this is that private and public grazing lands are not simple substitutes but are somewhat complementary: while ranchers with large private holding are better able to operate without public forage, they also are more likely to have large grazing allotments (a large number of permits).

We next observe that ranchers with larger public grazing utilization are more likely to accept a posted offer, all else equal. That is, of two ranchers that are otherwise equal and offered the same price to forgo entirely public grazing, the one with a greater current utilization of public grazing land is more likely to accept the offer. This is a somewhat confusing result; a simple analysis of ranchers' valuations would suggest that those ranchers with larger allotments, all else equal, would have a larger surplus and so be less likely to accept a posted offer.[14] We offer the following possible explanations. First, it is possible that public grazing is not of uniform quality and that large allotments are systematically associated with lower quality grazing. In this case, it is possible for the surplus value associated with large allotments to be less than those of small allotments. Of course, this does not explain why quantity of public grazing does not have similar implications for willingness to pay. Second, a rancher with a large allotment may be more willing to accept a buyout because the payment will be substantial, perhaps making it possible to get out of ranching entirely or to purchase enough private land so they are no longer dependent on public range. Finally, ranchers may believe that large allotments of public grazing are unlikely to persist given the pressures from government and environmental lobbies, while small allotments may be sustainable. In this case, those with large allotments may be more willing to accept an

[14] Recall that the allotment of public grazing is determined by the public land management agencies and not by the ranchers themselves, so we treat the public grazing allotment as exogenous.

offer of at least a partial buyout as they view the loss of these grazing allotments as inevitable.

The cross-product term of public grazing and private land ownership is also positive and highly statistically significant. This indicates that, as the extent of privately-owned land (allotment of public forage) increases, the eagerness with which a rancher with a larger public grazing allotment (private holdings) accepts the offer of a buyout also increases. Large operators appear readier to be bought out, suggesting that, all else equal, lifestyle is more important than ranching per se. With a significant buyout and a large homestead, a rancher can maintain the ranch lifestyle, living off their private lands without the concerns about potentially losing public forage.

The lifestyle factors we consider are two: whether the ranch is intended to be bequeathed and whether the rancher is an active participant in community events. The former is negative and strongly significant, meaning that those intending to pass the ranch on to their heir(s) are less likely, all else equal, to accept a posted offer, a result we might expect. The community event variable, in contrast, is positive and only weakly significant (ten percent); clearly, it is not picking up a commitment to ranch lifestyle as we might expect.

Finally, we consider ranchers attitude regarding the effect of grazing on the local environment. Recall the question asks whether endangered wildlife species are unaffected by livestock grazing, with strongly disagree equal to one and strongly agree equal to five. The majority of respondents agreed with this statement, so there is little support from ranchers for these concerns. The regression results indicate that the less concern a rancher has about the environmental effect of livestock grazing, the more likely they are to accept the posted offer and the less likely they are to pay the posted price.

Neither of these results accords with our expectations. Ranchers who do not view grazing as environmentally costly necessarily have a larger surplus than those ranchers who do view grazing as costly, as long as the latter are internalizing these environmental costs. The larger surplus means these ranchers should be less likely to accept a particular offer, all else equal. Similarly, such ranchers should be more likely to agree to pay a posted price than ranchers with greater environmental concerns.

We offer several possible explanations. Suppose people's views on how grazing affects wildlife depends upon how they use their public grazing allotment, more or less intensively. Those using it more intensively are more likely to accept that grazing threatens wildlife than otherwise. Then we might reason that more intensive users of public grazing are those with greater benefits. As a consequence, less intensive users (those with a high value of the threaten species variable) have a smaller surplus and are more likely to accept an offer and less likely to agree to pay a price.

A second possibility is that the result may reflect the context of the survey questions, which motivate reductions in AUMs due to environmental concerns. Those who do not think livestock grazing has an adverse impact on endangered wildlife species may see no reason to pay more for the privilege of grazing cattle, and hence may be less likely to agree to a posted price. Indeed, they may even see livestock grazing as a benefit to wildlife (meaning they should be subsidized even more than currently). Nonetheless, they would be more likely to accept a posted offer to sell grazing permits because, if livestock do increase wildlife numbers, there will be even more pressure in the future to reduce access to public forage as there is more competition for habitat and forage between wildlife and livestock.

Finally, the result may reflect ranchers' views of the dependence of the future of

public grazing on environmental concerns. Ranchers with a negative and pessimistic view of environmental concerns and issues may be more likely to agree that wildlife are not endangered by grazing, primarily as a statement against what they perceive to be growing support for land use policies dominated by environmental concerns. Consequently, these same ranchers may be pessimistic about the future of public grazing and so more willing to be bought out now. At the same time, they may be unwilling to pay more because the payment is considered an environmental payment.

Unfortunately, it is not possible to discriminate between these and other possible explanations given the data we have from the survey. Our results do suggest, however, that environmental concerns or attitudes may be influential in welfare valuation measures of the sort considered here and that there may well be an element of respondents using surveys for strategic purpose.

Statistical Tests of the Divergence between Welfare Measures

As discussed in the previous section, we can use the probit models to estimate valuations and to test for differences between the two measures. Table 5 reports mean willingness to accept and to pay for public grazing. To compare these payments, we consider discount rates of 2%, 4%, 7% and 11%.[15]

[15] The choice of these discount rates is guided by the following. The real rate of return on investments by large U.S. companies over the period 1926-1990 was about seven percent, after taxes. Given a corporate income tax rate of about 35%, the pre-tax rate of return is thus about eleven percent. Since individuals in the U.S. pay up to 50% in income taxes, the rate of return to individuals as owners of companies is closer to 4%, which can then be considered the rate at which people trade off spending over time. The U.S. Office of Management and Budget requires the use of seven percent for valuing costs and benefits external to the government and 4% for internal costs and benefits (Newell and Pizer 2003). Finally, range economists argue an appropriate rate of return to livestock production is 2%.

The estimate of mean willingness to accept is $262.65 per AUM while the estimate of mean willingness to pay is $2.21; both are statistically significant. From Table 1, we know that the values of posted offers to accept range between $5 and $200, below the estimated mean willingness to accept reported in Table 5, which is consistent with the relatively small number of offers accepted in the sample. Similarly, the estimated of mean willingness to pay of $2.21 is low relative to the range of posted payment offers ($1.50 to$20.62), consistent with the relatively small number of payment offers accepted in the sample. So the model seems to be doing a reasonable job: the predicted valuations are in line with observed behavior.

It is of some interest to compare the estimated willingness to pay valuation to the current fees for permit holders of public grazing allotments. In 2003, the fee charged was $1.35 per AUM, below but not statistically significantly different from our estimate of $2.21 per AUM (*p*-value of 0.282). If we simply focus on the point estimate, then current permit holders are willing to pay quite a bit more than the current grazing fee. In contrast, our valuation estimate is well below the $4.90 per AUM that is charged those without permits in Nevada (BLM 2003).

As discussed in the previous section, it is possible to estimate each individual's mean willingness to accept and willingness to pay, $-\frac{1}{\gamma_1}\beta_1^{'}\mathbf{x}_i$ and $-\frac{1}{\gamma_2}\beta_2^{'}\mathbf{x}_i$. As our first indication of how closely related are the willingness to pay and to accept valuations, we can consider the Pearson correlation coefficient; this is 0.60 for our sample, higher than that reported by Borges and Knetsch (1998) but below that one would expect if individuals' WTP valuations are closely tied to their WTA valuations.

The last part of Table 5 looks at this issue more formally by testing whether the mean

willingness to accept is significantly different from the mean willingness to pay measure adjusted by the discount rates identified above. For all discount rates considered, the willingness to accept valuation exceeds the adjusted willingness to pay valuation by a large amount and, despite the uncertainty surrounding our estimates, the differences are statistically significant. The differences we observe are consistent with others in the literature. With a discount rate of four percent, the results suggest that willingness to sell a grazing permit exceeds willingness to pay for current access to public forage by a factor of about 5 while for a discount rate of eleven percent the ratio is about 13. These are well within the 'reasonable' range of divergence found by Horowitz and McConnell (2002) for public and non-market goods (e.g., hunting permits), health and safety, and even some private goods.

Factors Contributing to the Divergence between WTA and WTP

We now examine divergence in the factors contributing to the difference between the two welfare measures in the manner laid out in the previous section. We continue to focus on the parsimonious bivariate probit model presented in Table 4. The results are presented in Table 6. The numbers can be interpreted as dollar values with positive numbers making a positive contribution to the valuation of interest. In the instance of a dichotomous variable such as the bequest motive, the coefficients have a very simple interpretation: the desire to pass the ranch on to your heir raises the willingness to accept valuation by nearly $100 per AUM.

The following variables make statistically significant contributions to the difference between the two valuations measures; acres owned, public grazing, financial stress, and bequest motive. The other lifestyle factor, participation in community events, and the

environmental variable do not make a statistically significant contribution. These conclusions are unchanged across different discount factors.

In the case of acres owned, or size of the ranch, there is a positive contribution to both the WTA valuation and the WTP valuation, but the effect is much larger for the former. Previously, we argued the positive contribution to willingness to accept might be explained by the dependence of larger ranches on public grazing, so that the two types of grazing are complementary. This is consistent with the positive effect it has on willingness to pay as well (though recall this variable is not statistically significant in the probit model itself). Viewed from this perspective, the fact that the effect is larger for WTA is consistent with the theoretical divergence in the two valuation measures arising from lack of close substitutes for the good being valued (Hanemann 1991). We can provide a rough guide to the magnitude of the contribution as well; the mean value of acres owned is approximately 10, so the contribution to the difference of $207 (using a 4% discount rate) is approximately $130, almost half.

Public grazing has the opposite effect, reducing both valuation measures (again, though, this variable is not statistically significant in the WTP probit equation). The relative magnitude of the two effects, however, is such that it brings the two valuation measures closer together. In general terms, the divergence of the valuation measures for the good (public grazing) is smaller the greater the allocation of the good. If we interpret the discrepancy as arising from an endowment effect, this implies that the effect is stronger for smaller quantities of the good (public grazing), a somewhat surprising result. As indicated previously, however, it may well be that small ranches as opposed to large ones, are all that is needed to maintain the 'ranch lifestyle'. If there is sufficient off-ranch income or a large

enough buyout, ranchers appear content to continue on a reduced scale.

Financial stress also makes a significant contribution to the discrepancy between the two valuation measures, raising the willingness to accept and lowering the willingness to pay. Financial stress tends to raise the willingness to accept valuation, as discussed previously, while at the same time reducing the willingness to pay valuation. While the former is somewhat difficult to explain, the latter would seem to be a straightforward prediction. As a general conjecture, it seems that the overall financial situation, including financial constraints, may bear on the divergence between the welfare measures. Notably, these sorts of issues are very unlikely to arise in standard experimental settings examining welfare measures.

Finally, we see a large contribution from the bequest motive. As noted previously, the desire to pass the ranch on to an heir raises the minimum willingness to accept by nearly $100; similarly, it lowers the maximum (adjusted) willingness to pay by roughly $50 (for a discount factor of four percent). If we view the bequest motive as evidence of a long-term commitment to ranching, both as an occupation as well as a lifestyle, we might conclude that lifestyle (broadly defined) is important for explaining the discrepancy between valuations.

5. Conclusions

The relationship between an individual's maximum willingness to pay and minimum willingness to accept compensation for the same change in a good or service has been the topic of considerable inquiry. The repeated findings from numerous survey-based contingent valuation field studies, which have now been replicated in various experimental and market settings, is that WTA and WTP diverge, with WTA typically much higher than WTP. The persistence of such disparities across numerous settings has defied any single explanation,

with researchers having offered a number of competing interpretations. The novelty of this paper is to evaluate the disparities and examine the contributions from different socioeconomic characteristics.

The study uses the results of the 2002 Nevada Ranch Survey, which provides a rich set of information about rancher characteristics as well as responses concerning willingness to pay for access to public grazing and willingness to accept payment for permanently giving up access to public grazing. The joint contingent valuation responses allow us to model the two valuations simultaneously using a bivariate probit model; this has the added advantage of allowing us to pursue inferences regarding the contribution of different factors to disparities in welfare measures.

The principal conclusions are easily summarized and have implications both for public grazing policies as well as research generally concerned with discrepancies in welfare measures. First, larger ranches are associated with greater discrepancies in valuations. We conjecture this may reflect the lack of viable substitutes for public grazing lands for larger ranches. Second, the size of allocation of public grazing is inversely related to the discrepancy in valuations, a result which we find surprising and which warrants further investigation. Third, financial stress contributes to the discrepancy; it would seem to be of some interest as to whether this result is more general. Finally, long-term commitment to ranching, either as an occupation or lifestyle, contributes substantially to the discrepancy.

It is useful to consider these results in terms of land use polices for grazing. Range economists have always argued that the public land agencies should promote trading of grazing rights. Where this has been done, however, trades have been remarkably few. One possible reason for the thin market is the persistence of a difference between WTA and WTP;

sellers require greater compensation than buyers are willing to pay. Our results provide support for this explanation of low trading. If successful markets in public grazing rights are desirable, our results suggest a number of directions worth exploring. First, it might be useful to focus attention on markets tailored to smaller ranches where valuations are more closely aligned. These are likely to be more successful, perhaps providing a starting point for more general markets to develop. Second, in ways that we do not properly understand, existing allocations seem to matter. As this factor is under the direct control of the land use agencies, a better understanding of this result might shed very useful information on improvements to the public grazing system. A further aspect of our results that may bear on land use polices concerns the evidence of lifestyle factors affecting welfare measures. The results suggest that ranchers with large public AUMs are more willing to be bought out, retreating to their owned acres. This is reinforced by our finding that WTA-WTP divergence is greater for small ranchers. Both are suggestive of lifestyle (and perhaps an endowment effect). While further investigation is needed, it does suggest that surplus is not the driving factor, but lifestyle appears to be the main driver as suggested by ranch economists. If this is the case, the public agencies need to re-think the issuance of large grazing allotments that also provide large subsidies.

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Table 1: Descriptive Statistics: Posted Prices

Variable	Description	Mean	SD[a]	Min	Max
p_{1i}	Posted price, willingness to pay ($/AUM)	$10.37	$4.89	$1.50	$20.62
p_{2i}	Posted price, willingness to accept ($/AUM)	$91.11	$54.55	$5.00	$200.00
Y_1	Discrete response to willingness to pay question; Y_1=1, WTP amount posted	0.11			
Y_2	Discrete response to willingness to accept question; Y_2=1, WTA amount posted	0.08			
	Joint frequencies of discrete response:				
	Y_1=1 and Y_2=1	0.02			
	Y_1=1 and Y_2=0	0.09			
	Y_1=0 and Y_2=0	0.83			
	Y_1=0 and Y_2=1	0.07			

Total number of observations: 194

[a]SD refers to standard deviation.

Table 2: Descriptive Statistics: Covariates[a]

Variable and Description	Mean	[b]SD/Freq[c]
Financial Factors and Education		
Income	3.974	[0.13, 0.18, 0.11, 0.11, 0.11, 0.36]
Categories 1-6, in $, 000s: [<30, 30-45, 45-60, 60-75, 75-90, >90]		
Acres owned, '000s, continuous	10.244	32.185
Public Grazing, '000 AUMs, continuous	5.655	10.336
Under financial stress, Likert scale [1, 5]	3.990	[0.03, 0.08, 0.13, 0.40, 0.36]
Education, Categories 1-8:	3.948	[0.02, 0.19, 0.36, 0.04, 0.23, 0.07, 0.05, 0.05]
1=grade school;		
2=high school;		
3=some college or technical school;		
4=technical training in armed forces;		
5=completed college;		
6=completed college, some grad. classes;		
7=completed Masters degree;		
8=completed PhD.		
Lifestyle or Quality of Life Factors		
Work off ranch, categories 0-2:	0.907	[0.55, 0.00, 0.45]
0 = no;		
1 = yes: part-time;		
2 = yes: full-time.		
Plan to pass ranch on to heir	0.897	
Indicator: yes = 1; no = 0		
Participant in community events	0.479	
Indicator: yes = 1; no = 0		
Attitude towards Environment		
Endangered wildlife are not threatened by grazing	4.036	[0.07, 0.07, 0.10, 0.26, 0.49]
Likert scale [1, 5][a]		
Total number of observations: 194		

[a] Likert scale [1, 5] range from 1 to 5 with 1 representing strongly disagree with the statement and 5 representing strongly agree.
[b] SD refers to standard deviation.
[c] Frequency is the proportion of each category in the total of 194 observations

Table 3: Probit Estimation Results for WTP and WTA, General Models[a]

Explanatory Variable	Bivariate Probit Model		Univariate Probit Model	
	WTA	WTP	WTA	WTP
Constant	-2.369**	2.974***	-2.919***	3.156***
	(1.094)	(1.096)	(1.134)	(1.017)
Posted offer (p_{ji})	0.018***	-0.269***	0.018***	-0.271***
	(0.005)	(0.060)	(0.005)	(0.058)
Financial Factors and Education				
Income	-0.142*	0.013	-0.144	0.004
	(0.085)	(0.102)	(0.096)	(0.099)
Acres owned	-0.244***	0.003	-0.218***	0.003
	(0.064)	(0.005)	(0.059)	(0.005)
Public Grazing AUMs	0.183***	-0.024	0.178***	-0.011
	(0.052)	(0.034)	(0.054)	(0.035)
Acres owned x AUMs	0.002***	0.000	0.002***	0.000
	(0.001)	(0.000)	(0.001)	(0.000)
Under financial stress	-0.408**	-0.112	-0.408*	-0.137
	(0.188)	(0.146)	(0.218)	(0.148)
Education	0.071	-0.070	0.087	-0.092
	(0.104)	(0.077)	(0.103)	(0.077)
Lifestyle Factors				
Work off ranch	-0.050	0.120	-0.067	0.169
	(0.212)	(0.177)	(0.221)	(0.173)
Plan to pass ranch on to heir	-1.755***	-0.584	-1.737**	-0.682*
	(0.672)	(0.398)	(0.725)	(0.409)
Participant in community events	0.542*	-0.365	0.643	-0.450
	(0.326)	(0.341)	(0.358)	(0.321)
Attitudes towards Environment				
Endangered wildlife	0.432**	-0.261**	0.507*	-0.236*
are not threatened by grazing	(0.194)	(0.124)	(0.229)	(0.124)
ρ	0.748**		–	–
	(0.225)			
Log likelihood	–65.625		-29.429	-38.162
Pseudo-R^2	0.459		0.467	0.426

[a] Total number of observation is 194. Numbers are point estimates with heteroskedasticity robust standard erros provided in brackets. A *** denotes statistical significance at the 1% level; ** at the 5% level; * at the 10% level for a two-sided t-test using the standard normal distribution. The psuedo-R^2 is from McFadden (1974). See Tables 1 and 2 for variable definitions.

Table 4: Probit Estimation Results for WTP and WTA, Specific Models[a]

Explanatory Variable	Bivariate Probit Model		Univariate Probit Model	
	WTA	WTP	WTA	WTP
Constant	-2.125**	2.619***	-2.721**	2.749***
	(1.001)	(0.889)	(1.064)	(0.903)
Posted offer (p_{ji})	0.018***	-0.261***	0.018***	-0.262***
	(0.005)	(0.058)	(0.005)	(0.059)
Financial Factors and Education				
Income	-0.148*	0.026	-0.149*	0.024
	(0.079)	(0.094)	(0.087)	(0.092)
Acres owned	-0.240***	0.001	-0.210***	0.001
	(0.069)	(0.004)	(0.061)	(0.004)
Public Grazing AUMs	0.192***	-0.037	0.186***	-0.025
	(0.048)	(0.032)	(0.049)	(0.036)
Acres owned x AUMs	0.002**	0.000	0.002**	0.000
	(0.001)	(0.000)	(0.001)	(0.000)
Under financial stress	-0.408**	-0.085	-0.385*	-0.109
	(0.178)	(0.132)	(0.207)	(0.140)
Lifestyle Factors				
Plan to pass ranch on to heir	-1.760***	-0.488	-1.693**	-0.583
	(0.682)	(0.383)	(0.726)	(0.402)
Participant in community events	0.535*	-0.348	0.631*	-0.431
	(0.320)	(0.314)	(0.346)	(0.304)
Attitudes towards Environment				
Endangered wildlife	0.413**	-0.270**	0.483**	-0.247*
are not threatened by grazing	(0.167)	(0.125)	(0.216)	(0.127)
ρ	0.823**		–	–
	(0.200)			
Log likelihood	–66.377		-29.719	-39.043
LR Test (p-value)[a]	0.826		0.415	0.748
Pseudo-R^2	0.453		0.462	0.413

[a] As for Table 3. LR Test reports the p-value for the χ^2 (q) distributed test of the restriction imposed in these models relative to the general models of Table 3. For the bivariate model, q=4; for the univariate models, q=2.

Table 5: Valuation Measure[a]

Valuations	Estimate	s.e.	p-value
$\overline{WTA} = -\frac{1}{\hat{\gamma}_1}\hat{\beta}_1' \bar{x}$	262.65	26.78	0.000
$\overline{WTP} = -\frac{1}{\hat{\gamma}_2}\hat{\beta}_2' \bar{x}$	2.21	1.04	0.033

Test of Divergence				
Discount Rate	$\overline{WTA} - \overline{WTP}/r$	s.e.	p-value	$\overline{WTA}/(\overline{WTP}/r)$
2%	152.27	61.03	0.013	2.38
4%	207.46	39.40	0.000	4.75
7%	231.11	32.10	0.000	8.32
11%	242.58	29.43	0.000	13.07

[a] Reported Standard errors are based on a first order approximation of the valuation function conditional on the estimated mean, $\bar{x}$. p-values are for a two-sided test of the null-hypothesis that the valuations or functions of the valuations are statistically different from zero.

Table 6: Contributions to Divergence of Valuation Measures[a]

Explanatory Variable	WTA $(-\hat{\beta}_{1k}/\hat{\gamma}_1)$	WTP $(-\hat{\beta}_{2k}/\hat{\gamma}_2 \times 1/r)$			
		Discount Rate			
		2%	4%	7%	11%
Financial Factors					
Income	8.066	5.009	2.504	1.431	0.911
		(0.875)	(0.605)	(0.361)	(0.212)
Acres owned	13.096	0.204	0.102	0.058	0.037
		(0.000)	(0.000)	(0.000)	(0.000)
Public Grazing AUMs	-10.482	-7.013	-3.507	-2.003	-1.275
		(0.613)	(0.070)	(0.002)	(0.000)
Acres owned x AUMs	-0.117	0.062	0.031	0.018	0.011
		(0.011)	(0.006)	(0.006)	(0.007)
Under financial stress	22.291	-16.400	-8.200	-4.686	-2.982
		(0.166)	(0.054)	(0.015)	(0.006)
Lifestyle Factors					
Plan to pass ranch on heir	96.158	-93.689	-46.794	-26.741	-17.016
		(0.039)	(0.012)	(0.004)	(0.002)
Participant in community events	-29.219	-66.817	-33.408	-19.090	-12.148
		(0.597)	(0.917)	(0.725)	(0.482)
Attitudes towards Environment					
Endangered wildlife are not threatened by grazing	-22.582	-51.871	-25.935	-14.820	-9.431
		(0.288)	(0.840)	(0.541)	(0.240)

[a] Numbers in labeled rows are coefficient ratios; numbers below are marginal significance levels for the hypothesis test that the WTA component and the adjusted WTP component are equal; that is, $(-\hat{\beta}_{2k}/\hat{\gamma}_2) = (-\hat{\beta}_{1k}/\hat{\gamma}_1 \times 1/r)$. Inference is based upon first order approximations.