Structuring Legal Trade in Rhino Horn to Incentivize the Participation of South African Private Landowners

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Highlights

- Novel wildlife trade application of the best-worst choice methodology
- Horn trade market structures and payment amounts affect market participation.
- Market attributes can be strategically designed to increase participation.

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Abstract. There is contentious debate in the literature regarding the conservation efficacy of the international rhinoceros horn trade ban. Because the ban has been in effect for 40 years, it is unclear how potential legal horn trade should be structured to attain rhino conservation on private lands. We sought to fill this gap by eliciting the preferences of South African private wildlife industry members (who conserve a third of South Africa's rhinoceroses) for international trade in rhino horn. We used a combination of best-worst scaling and dichotomous choice experiments to determine wildlife industry members' preferences for three features of legal trade: market structure; payment/kg horn; and whether landowners should be required to conserve a minimum amount of land per rhino before they may enter the market. Results indicate that respondents preferred payments of at least ZAR 150,000/kg (USD $11,500) and that legal trade not be regulated by government organizations. Respondents did not have clear preferences about whether market participants should be required to meet a minimum land requirement per rhino. Our results provide insights into how potential horn trade policy may be structured to meet the financial needs of private landowners, while securing the conservation of rhinos on private lands.

Key words: best-worst scaling, dichotomous choice, market structure, reservation payment, rhinoceros conservation, stated preference survey, wildlife ranching

1. Introduction

Since 1977, international trade in all rhinoceros (hereafter, 'rhino') parts, including horn, has been largely banned by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). However, with the escalation of poaching events that began in 2008 (Biggs et al. 2013), there is renewed debate about the efficacy of the trade ban (see Biggs et al. 2013; Di Minin et al. 2014; Ferreira et al. 2014; Challender et al. 2015a; Crookes & Blignaut 2015; Haas & Ferreira 2016). Criticisms of the efficacy of the CITES ban on rhino trade form part of a larger critique of the limitations of CITES, including: "non-compliance, an over reliance on regulation, lack of knowledge and monitoring of listed species, ignorance of market forces, and influence among CITES actors" (Challender et al. 2015a).

Several southern African rhino range states have advocated for legal international trade in rhino horn, based on the argument that market-based, supply-side interventions are necessary to ensure the continued conservation of the rhino. Although it was unsuccessful, Swaziland proposed reversing the international trade ban for their rhino population at the CITES Conference of Parties in 2016 (CITES Management Authority 2016). South Africa contains 80% of the world's rhino population (Rademeyer 2016) and was obliged to lift its domestic moratorium on rhino horn trade in April 2017, following successful legal action by the private sector. Domestic commercial trade of rhino horn is now legal in South Africa and the first domestic sale occurred in August 2017 (Du Toit 2017).

Efforts to legalize the trade in rhino horn have stimulated the international debate about the role of market-based, supply-side interventions (including wildlife breeding, wildlife farming, and wild harvesting) in attaining the conservation of endangered species, an issue that is highly contested within the literature (Phelps et al. 2014a). Proponents for supply-side

interventions argue that bans and other policies to restrict or regulate wildlife harvesting and trade have failed to secure conservation outcomes because they: (1) require extensive monitoring, enforcement and resources (Phelps et al. 2010; Weber et al. 2015); (2) inflate the prices of wildlife products by restricting supply and thereby incentivizing illicit trade; (3) "reduce the complex nature of wildlife trade, which is intrinsically linked to poverty alleviation, tenure rights, rural livelihoods and cultural traditions, into a simple law enforcement problem" (Challender et al. 2015a: 140); and (4) fail to consider consumer demand for wildlife products, including consumer preferences, social norms that motivate demand, and demand elasticity (Rivalan et al. 2007; Underwood et al. 2013; Challender et al. 2015a,b; Weber et al. 2015). These individuals have argued that providing competition for illegally-sourced products through the provision of legal, high-quality farmed products and/or sustainably managed wild-harvested products may reduce illegal harvesting (Bulte & Damania 2005), provide alternatives for conscientious consumers, and create financial incentives to engage in the legal market (Larsen & Olsen 2007; Lubbe & Verpoorte 2011).

Although economic theory suggests that wildlife trade has the potential to attain conservation outcomes, other researchers have noted that supply-side interventions may fail or only have moderate success in attaining conservation outcomes for several reasons: (1) wild-sourced and farmed products (including rhino horn) may not be substitutes (Dutton et al. 2011; Phelps et al. 2014a,b; Liu et al. 2016; Hanley et al. 2017); (2) consumers may have preferences for wild-collected products, including illegally-harvested, wild rhino horn (Phelps et al. 2014a; Liu et al. 2016; Hanley et al. 2017; Nuno et al. 2017); and (3) illegally-harvested, wild-sourced products may be laundered via breeding facilities and legal trade (Phelps et al. 2014b). However, these researchers have also found that consumers may prefer that species are not killed in the

process of harvesting products, such as rhino horn (Hanley et al. 2017), and may be influenced by a desire to protect endangered species (Liu et al. 2016). As such, they have suggested that while market-based conservation strategies may not be effective by themselves, they may be useful supplements to regulation and education (Phelps et al. 2014a).

Given the paucity of information on the role of legal trade in wildlife conservation, further objective research on supply-side interventions is required (Challender et al. 2015a). To date, the literature on legalizing rhino horn trade has tended to advocate for or against trade without clearly articulating assumptions about how trade would be structured (Crookes & Blignaut 2015; Haas & Ferreira 2016). For example, although studies discuss the potential implementation of central selling organizations (CSOs) to manage trade (Biggs et al. 2013; Ferreira et al. 2014), the agency that should be responsible for running the CSO has not been addressed. Equally importantly, there is scant literature on private landowners' preferences for how legal trade should be structured. To the best of our knowledge, there is no empirical research on the payment per unit horn landowners would require to enter the legal market.

Accordingly, we used stated preference choice experiments to better understand the supply-side market preferences of current and potential suppliers of rhino horn -- specifically private landowners and wildlife ranchers in South Africa[1]. Private ranchers are critical

[1] We are aware of only three studies in which choice experiments have been used to study the issue of rhino conservation, and none of these studies focused on supply-side analysis. Adhikari et al. (2005) studied locals' preferences for rhino management in Nepalese parks, Lee and Du Preez (2015) investigated tourists' preferences for rhino conservation on a private reserve in South Africa, and Hanley et al. (2017) studied willingness to pay for rhino horn by existing and

stakeholders in rhino conservation in South Africa as a third of rhinos are currently protected on private lands (Rademeyer 2016; Child 2012). South Africa has adopted a sustainable use approach to wildlife management, where private landowners are able to secure the user rights to wildlife on their lands (Pienaar et al. 2017). In this system, wildlife stewardship serves as a source of revenue (e.g. through hunting, breeding wildlife, or photographic tourism), thus incentivizing wildlife management as a land use.

However, wildlife ranching has come under criticism because a subset of ranchers engage in intensive wildlife management, i.e. the breeding of high-value wildlife on smaller areas of land. A key concern expressed by opponents of rhino horn trade is that this trade would incentivize ranchers to intensively 'farm' rhinos by keeping them in small enclosures, in order to more easily harvest their horn. In addition to studying wildlife industry members' preferences for market structure and the reservation payments at which they would enter different markets, we also investigated whether industry members would support rules that would require them to meet a minimum land requirement per rhino before they would be permitted to enter the legal trade in rhino horn. We used this minimum land requirement as a proxy for a rule that would prohibit market entry if individuals engage in intensive rhino farming.

2. Methods

2.1 Best-Worst Choice Methodology

In 2017 we administered a survey to private wildlife industry members in South Africa to elicit their preferences for how legal international trade in rhino horn should be facilitated, and

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potential future consumers in Vietnam. Additionally, Wright et al. (2016) used qualitative analysis to explore rhino owners' attitudes towards legalizing rhino horn trade.

whether they would choose to participate in legal trade. In designing the survey, we utilized the best-worst choice (BWC) methodology (Coast et al. 2006), which combines best-worst scaling (BWS) with dichotomous choice experiments (DCE). Survey respondents complete two tasks: 1) they choose a 'best' and 'worst' attribute from a given policy profile (the BWS task); and 2) they 'accept' or 'reject' the entire policy profile (the DCE task). We used the BWS task to determine which attributes of legal trade respondents most and least preferred. We used the DCE task to determine whether respondents would choose to sell rhino horn to the international market, and, if so, at what payment they would enter the market (hereafter, the reservation payment).

The BWS task measures extremes in utility space, which is cognitively easier for respondents (Louviere & Islam 2008), and generates more consistent measures than considering 'middle ground' rankings (Flynn et al. 2008). Best-worst scaling identifies where supply-side market attributes (in our case, market structure, a minimum land requirement per rhino, and the payment per unit horn) fall on respondents' underlying scale of utility, or preference (Lusk & Parker 2009). The relative position of each attribute on the underlying utility scale is determined, which in turn provides information on which attributes of legal trade are more or less preferred by respondents (Lusk & Briggeman 2009; Lusk & Parker 2009).

However, BWS does not provide information on the attractiveness of legal trade relative to the status quo of no legal trade in rhino horn (Flynn et al. 2008). Namely, the BWS task forces respondents to choose amongst alternatives (i.e., no opt-out option), which goes counter to economic theory where you have the option to not engage in a given transaction. By including the DCE task, the BWC methodology allowed us to determine whether respondents would participate in legal trade in rhino horn, the reservation payment at which respondents would enter

the market, and how this reservation payment varied according to market structure (see Pienaar et al. 2014).

2.2 Survey Design

We developed the BWC attributes and levels based on interviews with rhino horn trade stakeholders (including wildlife trade consultants, rhino owners, biologists in South Africa's national park system, local non-governmental organizations, and members of the wildlife industry; see Rubino and Pienaar, 2018) and by reviewing the academic literature on horn trade. The first attribute we included in the BWC experiments was the market structure (Tab. 1). Central selling organizations (CSOs) have been suggested as a means to permit legal trade of rhino horn while still ensuring market regulation and transparency (Biggs et al. 2013; Ferreira et al. 2014). We included three CSO levels in the BWC: 1) South Africa's Department of Environmental Affairs (DEA); 2) Wildlife Ranching South Africa (WRSA), a prominent wildlife ranching industry organization; and 3) De Beers, a company well-known for its management of diamond trade in South Africa (as per Martin 2011). By including these three organizations in the BWC, we were able to measure respondents' preferences for government and non-government management of legal trade. We were also able to study whether respondents preferred that the legal trade in rhino horn be managed by a wildlife-related entity or an independent entity outside the wildlife industry. In addition, we included unregulated market structures in the BWC, namely: an auction structure, which was recently used in South Africa's first domestic, commercial horn sale (Du Toit 2017); and open trading, whereby horn could be sold among individuals like most other commodities (Tab. 1).

[Insert Table 1 here]

To accommodate both the CSO market structure and the unregulated market structures, two separate choice experiments were created. This was necessary to ensure that the levels of the market structure attribute were comparable (Coast et al. 2006). Three CSO management organization levels and two unregulated market structure levels cannot be considered different levels of the same attribute. Accordingly, we administered two choice experiments (the CSO Experiment and the Unregulated Market Experiment) to all respondents where the market structure attributes and levels differed, but the other attributes and levels were identical.

The second attribute we included in the BWC experiments was the payment per kilogram of horn, framed as either a buying price set by the CSO or the average price the respondent could expect to receive at an auction or through open trading. These attribute levels were determined using our interviews with rhino horn trade experts, mainly wildlife trade consultants and rhino owners. These experts estimated that rhino owners would be able to cover their rhino-related costs and make a small profit at the middle payment level of ZAR 150,000/kg (approximately $11,500). The extreme payment levels were chosen to represent prices where rhino owners would definitely not be able to cover their costs (ZAR 15,000 or ~$1,000/kg) and where rhino owners would be making a sizeable profit (ZAR 500,000 or ~$38,000/kg, which is approximately the price of gold/kg). We attempted to keep this maximum payment level lower than the black market price of horn, which has been estimated at approximately $65,000/kg (Hubschle 2016), but which may range from approximately $30,000/kg to $120,000/kg (Crosta et al. 2017). There have also been instances of pseudo-trophy hunting, where rhinos were hunted under the guise of trophy hunting (at average 2012 prices of US $85,000 and US $300,000 for white and black rhinos, respectively; Saayman & Saayman, 2017) but for the purposes of obtaining rhino horn to sell on the black market (Hubschle 2016). We posited that it is unlikely

the legal price for rhino horn would reach the black market price (which is artificially inflated due to a lack of legal competition), although the legal price could theoretically exceed the current black market prices if consumers were willing to pay a sufficiently high price premium for legally-sourced, sustainably-harvested horn.

Finally, we included a minimum land requirement per rhino in the BWC. We selected this third attribute in recognition of concerns that horn trade legalization may result in intensive rhino farming, with limited conservation impact (Wright et al. 2016). Again, we used interviews with rhino owners and other experts to determine the levels for this attribute. No minimum land requirement represented a scenario whereby trade legalization might result in intensive rhino farming. Setting the minimum land requirement at 50 or 100 ha/rhino represented an effort to link horn trade legalization with the conservation of rhino habitat and management of rhinos on extensive properties. Rhino owners and conservation experts expressed the opinion that a minimum land requirement of 100 ha/rhino represents a strong commitment to habitat conservation. Assuming ample food and water is available, they argued that such an expansive territory is not ecologically necessary for black or white rhinos.[2]

We used optimal designs generated by SAS statistical software to maximize the information derived from the choice task while minimizing the length of the survey (Soto et al. 2016). The optimal designs for both choice experiments (CSO Experiment D-efficiency = 92.76; Unregulated Market Experiment D-efficiency = 91.38) created ten choice tasks (i.e., supply-side

[2] Although appropriate minimum land requirements can be debated on ecological or ethical grounds, that is not the purpose of this paper. We used these initial levels of 0, 50, and 100 ha/rhino as an exploratory starting point for research. The debate regarding what constitutes "farmed" versus "wild" animals is highly complex, and beyond the scope of this paper.

market scenarios) for each of the experiments. To reduce the length of the survey and respondents' cognitive burden, each choice experiment was split into two blocks using SAS statistical software. Respondents were given five market scenarios from each experiment (i.e. five CSO market scenarios and five unregulated market scenarios).

For each scenario, respondents were asked to choose their most and least preferred attribute of the market and state whether they would enter the market (Fig. 1). We provided several dissonance minimizing options to avoid hypothetical bias (i.e., to improve the accuracy of estimated participation; Morrison & Brown 2009). These dissonance minimizing response categories, which were coded as refusal to enter the market, allowed respondents to answer honestly that they would not participate in the market, while still showing support for legal trade.

Respondents were asked different follow-up questions for each market scenario depending on whether they agreed to participate in the market or not. If they rejected participation, respondents were asked why they did not want to enter the market. They could choose from response categories related to the market structure (e.g., 'The price is not high enough'), rhino ownership (e.g., 'I will never be interested in owning rhinos'), or they could write in their own response. These options were used to identify protest responses (Freeman et al. 2014). If respondents agreed to participate, they were asked to rate their certainty that they would enter the market on a 10-point scale (with higher numbers indicating increasing certainty). We used the certainty-7 correction (where acceptances with a certainty of <7 are recoded as rejections, per Morrison & Brown 2009) as an additional method to mitigate bias.

Other questions included in the survey related to respondents' attitudes towards horn trade legalization and the government, as well as demographic information. All questions were

designed and ordered according to the best practices of Dillman et al. (2009). This survey was approved by the University of Florida Institutional Review Board (IRB201601671).

2.3 Survey Implementation

We defined our study population as individuals who participate in the private wildlife ranching industry in South Africa because these are the individuals most likely to engage in rhino horn trade in the short- to medium-term. The survey was pretested (see Dillman et al. 2009) with survey methodology experts and members of our study population. The survey was offered in both English and Afrikaans, and was primarily distributed online via Qualtrics Survey software, although some respondents preferred to take the survey by phone or in-person.

We used multiple distribution channels to recruit survey respondents. We cultivated lists of email addresses and phone numbers for potential respondents by conducting internet searches of companies that were listed on the Professional Hunters' Association of South Africa (PHASA) membership website and companies that advertised in the Wildlife Ranching South Africa (WRSA) magazine. We also conducted general internet searches for other relevant South African companies using keywords such as "wildlife/game ranching", "wildlife/game breeding", "wildlife photographic tourism", and "game hunting". A link to the survey was included in weekly newsletters to PHASA and South African Hunters and Game Conservation Association (SAHGCA) members. We attended the Safari Club International convention to distribute flyers directing hunting and photographic tourism operators to the online survey, and follow-up emails were sent with a direct link to the survey. Finally, some respondents were eager to share the survey with colleagues in the wildlife industry, so we also engaged in referral-based sampling (see Biernacki & Waldorf 1981) to increase our sample size. When a phone number was

available, we made follow up phone calls to all potential respondents who were initially contacted by email.

2.4 Econometric Analysis of the BWS Task

We estimated different econometric models for the two BWC tasks: a random parameters logit (RPL, or mixed logit) model for the BWS task of choosing the best and worst policy attribute pair (Lusk & Briggeman 2009), and a logit model for the binary choice task of choosing whether to participate in horn trade (Train 2012).

Best-worst scaling analyses can be conducted as paired or marginal estimations at either the respondent or sample level (Flynn et al. 2007). We used paired estimation at the respondent level because marginal estimation is an approximation of paired estimation (Flynn et al. 2007), and respondent-level analyses consider heterogeneity across respondents (Louviere et al. 2015). We used a random parameters logit (RPL) model for our analysis. This analysis is similar to that of the more rigid multinomial logit (MNL) model, where each best-worst pair choice is treated as a distinct outcome amongst $J(J-1)$ options (Flynn et al. 2007). Namely, our study had 3 items per policy scenario ($J = 3$), which translated into $J(J-1) = 6$ different best-worst pair combinations per scenario. Per Lusk and Briggeman (2009), if j and k are items and j is selected as best and k as worst, then λ_j and λ_k represent the locations of their respective values on individual i's underlying utility scale. $I_{ij} = \lambda_j + \varepsilon_{ij}$, where ε_{ij} is a random error term, representing individual i's latent unobserved level of utility. Best item j and worst item k represent the maximum difference between all possible $J(J-1)$ items on individual i's underlying utility scale (Lusk & Briggeman 2009). The probability that individual i selected j and k is represented as: $\Pr[(I_{ij} - I_{ik}) > (I_{il} - I_{im})]$, where l and m are all other possible best-worst pair combinations. The following MNL equation can be applied (assuming i.i.d. type I extreme value errors):

$$\text{Prob}(j \text{ is selected as best}, k \text{ as worst}) = \frac{e^{\lambda_j - \lambda_k}}{\sum_{l=1}^{J}\sum_{m=1}^{J} e^{\lambda_l - \lambda_m}}$$

Maximum likelihood techniques were used to estimate the λ_j utility parameters. Each policy scenario (i.e., question) was expanded into $J(J-1)$ distinct outcomes, where the dependent choice variable took a value of 1 if that best-worst pair was selected and 0 if not. This model allows for two different types of independent variables: attribute impact variables (mean utility across all levels of an attribute) and level scale values (deviations from mean utility; Flynn et al., 2007). Following Flynn et al. (2007), attribute impact variables were coded as 1 if any level of the corresponding attribute was selected as "best", -1 if "worst", and 0 if otherwise. Level scale values were effects coded (Tab. 1), where one level is embedded as -1 and its coefficient is later recovered by calculating the negative sum of the 'included' coefficients, from the correspondent attribute. Similarly, these took a value of 1 if the level was chosen as 'best', -1 if 'worst', 0 if not chosen, and the inverse if the embedded effects coded level is chosen.

Parameter λ_j represents the location of item *j* on individual *i*'s underlying utility scale. As noted by Lusk and Briggeman (2009), this location is relative to another item that is omitted to prevent the dummy variable trap. The omitted item is normalized to 0 on the utility scale, thus serving as a reference point for all other utility parameter estimates. As such, the signs and magnitudes of parameter estimates are relative to the reference point of 0 and the parameter estimates can be directly compared (Lusk & Briggeman 2009; Lusk & Parker 2009).

But the MNL model suffers from several limitations, including the assumptions of preference homogeneity and independence of irrelevant alternatives (IIA; Train 1998). To avoid these restrictions, we utilized the more flexible random parameters logit (RPL) model. RPL allows for random variation in preferences of respondents. It is also not restricted by the IIA assumption (Train 1998; Lusk & Briggeman 2009). The RPL preference parameters are specific

to individual *i*, and thus are specified as $\tilde{\lambda}_{ij} = \tilde{\lambda}_j + \sigma_j \mu_{ij}$, consisting of the mean ($\tilde{\lambda}_j$) and standard deviation (σ_j) of λ_j in the population and a normally distributed random error term with a mean of 0 (μ_{ij}). The probability statement for this new specification implies normally distributed preferences for attribute levels (Lusk & Briggeman 2009). Thus, parameter coefficients vary randomly over people and are no longer fixed. RPL models were estimated using the 'mixlogit' command in the STATA statistical software package.

2.5 Econometric Analysis of the DCE Task

The dependent variable of the binary choice task was assigned a value of 1 if the policy profile was accepted ("yes") and 0 if it was not (including "no" responses and dissonance minimizing responses). We analyzed these data using two logit model specifications, one in which all covariates were effects-coded and one in which the "payment" attribute was quantitatively coded to estimate reservation payments (Pienaar et al. 2014; Soto et al. 2016). Logit models were estimated using the 'logit' command in STATA.

Because we included up to 18 covariates in our initial models to explain variation in the dichotomous choice responses, we used the corrected Akaike Information Criterion (AICc) to find the most parsimonious models. Two covariates ("attitude towards horn trade" and "distrust of government") were derived using principal factor analysis (Tab. 2), which is used to reduce large sets of variables into smaller sets of latent underlying factors (Meigs 2000). Respondents' "attitude towards horn trade" was derived from their answers to four questions: (1) respondents' opinions about whether it would be acceptable if legal trade resulted in intensive rhino farming; and respondents' beliefs that legal international trade will (2) benefit rhino owners, (3) benefit rhino conservation, and (4) reduce rhino poaching. "Distrust of government" was derived from respondents' beliefs that interacting with (1) the DEA and (2) their provincial environmental

department increases the risk of poaching events. We used an eigenvalue threshold of 1.0 to retain factors (per Meigs 2000). Factor loadings were used to generate weighted scores that measured respondents' attitudes toward trade and the government.

[Insert Table 2]

3. Results

3.1 Response Rates

We utilized 169 completed survey responses in our analysis. Response rates varied depending on distribution channel. We achieved a 100% response rate for pre-tests and referrals, 18.4% for SCI convention attendees, 16.4% for the PHASA membership list, and 12.2% for our cultivated list. We were unable to calculate the response rates for the two newsletters because we could not determine how many individuals received the link to the survey.

3.2 Sociodemographic Characteristics of Respondents

Most respondents were male (95.3%), and their median age range was 46 to 55 years old (Tab. 3). Respondents' annual, pre-tax income created a U-shaped distribution where 24.9% of respondents grossed ZAR 1 million or less (~$70,200 2017 USD), and 20.1% grossed greater than ZAR 7 million (~$491,600). Approximately a third (32.0%) of all respondents owned, leased, and/or managed more than 5,000 hectares of land. Notably, 19.5% of our sample (33 respondents) stated they were current rhino owners. This accounts for approximately 10% of rhino owners in South Africa (CITES Management Authority 2016). Over 65% of respondents indicated they do not currently own rhinos and 14.2% preferred not to disclose whether they own rhinos. Respondents' attitudes towards horn trade legalization were, on average, very positive,

whereas their attitudes towards the government were neutral (Tab. 3). On average, there was a high level of concern about land reform among respondents.

[Insert Table 3 here]

3.3 Best-Worst Scaling Task

Negative signs on coefficients in the random parameters logit (RPL) models indicate that the variables fall on the negative side of the reference case, not a negative relationship with the dependent choice variable. In both the CSO and unregulated market RPL models, the minimum land requirement attribute was omitted and used as a reference case; i.e. its attribute impact (or mean utility across all levels) is equal to 0 (Tab. 4).

[Insert Table 4 here]

3.3.1 CSO RPL Model Results

In the CSO RPL model, the mean and standard deviation coefficients for the attribute impacts (market structure and rhino horn payment) were statistically significant. Relative to the reference case (the minimum land requirement), regulation of rhino horn trade by a CSO was not preferred by respondents (significant mean coefficient of -0.244), while receiving payments for rhino horn was preferred (significant mean coefficient of 0.672) (Tab. 4). However, respondents exhibited preference heterogeneity with respect to both attribute impacts (statistically significant coefficient standard deviations).

Based on the level scale values (i.e., deviations from mean utility), respondents preferred that WRSA rather than the Department of Environmental Affairs (DEA) manage the CSO (mean coefficient of 1.84). However, respondents displayed heterogeneity in terms of the strength of their preference for the WRSA (standard deviation coefficient of 1.20). Respondents also displayed preference heterogeneity with respect to De Beers managing the CSO (standard

deviation coefficient of 1.27), with some respondents not preferring that De Beers run the CSO while other respondents preferred this alternative, relative to the DEA operating the CSO.

The level scale values for the rhino horn payment followed the theoretically expected pattern of increasing preference for higher payments (i.e., lower payments were not preferred compared to the reference case, and higher payments were preferred). The median payment of ZAR 150,000 (approximately $11,500) marked an approximate threshold from not preferred to preferred, relative to the reference case. There was no evidence of preference heterogeneity related to payment levels.

Level scale values for the minimum land requirement (i.e., no minimum requirement, 50 ha/rhino, and 100 ha/rhino) were not statistically significant at the 5% level. However, there was evidence of preference heterogeneity with regards to a minimum land requirement of 100 ha/rhino (standard deviation coefficient of 0.91). Based on the magnitude of the standard deviation coefficient, some respondents did not prefer this minimum land requirement and others preferred it, relative to the reference case.

3.3.2 Unregulated Market RPL Model results

In the unregulated market RPL model, the mean and standard deviation coefficients for the attribute impacts (market structure and rhino horn payment) were again statistically significant (Tab. 4). However, for this model respondents preferred both the market structure and the rhino horn payment, relative to the reference case – even when accounting for preference heterogeneity.

Based on the level scale values, on average, respondents preferred auctions to open trading (mean coefficient of -0.27). However, respondents exhibited heterogeneity of preferences with a subset of respondents preferring open trading. Similar to the CSO model, respondents

preferred higher payments for rhino horn, with no heterogeneity of preferences for payment. On average, respondents preferred a minimum land requirement of 100 ha/rhino, relative to the reference case. Respondents displayed no preference heterogeneity with respect to minimum land requirements.

3.4 Dichotomous Choice Task

The results for the dichotomous choice task were analyzed for protest responses (Freeman et al. 2014), of which none were found, and adjusted using the certainty-7 correction (Morrison & Brown 2009). The two reported logit models for each experiment (Tab. 5) were the most parsimonious models according to the AICc. For each experiment (the CSO and the Unregulated Market experiments), we generated an all effects-coded model, providing parameter estimates for each choice experiment attribute, and a model where the payment per unit horn was quantitatively coded (referred to as the 'continuous payment model'). We used this latter model to estimate reservation payments, or the minimum payment required for a respondent to enter legal trade in rhino horn (Tab. 6). For the logit models, positive coefficients represent an increased probability that respondents would enter the market and negative coefficients represent a decreased probability of market entry.

[Insert Tables 5 and 6]

3.4.1 CSO Logit Model Results

For the CSO logit models, the results are similar for both the all effects-coded model (AICc = 1,007.26) and the continuous payment model (AICc = 1,004.89) (Tab. 5). In both models, the probability that respondents would enter the legal trade in rhino horn increased if the CSO was managed by WRSA. A CSO managed by De Beers was not a significant determinant of market participation. The all effects-coded model provided us with estimates for the discrete

payment attributes, where we saw the theoretically expected pattern of increasing probabilities of market participation as the rhino horn payment increased. The two lowest payments (≤ZAR 50,000, ~$4,000/kg) were associated with decreased probability of participation in the market and the highest two (≥ZAR 300,000, ~$23,000/kg) were associated with increased probability of market participation. In the continuous payment model, the "payment" coefficient was positive and significant at the 1% level. None of the minimum land requirement attributes were significant determinants of market participation in either model.

There was a positive correlation between respondents' attitudes towards horn trade and the probability that they would enter the market (Tab. 5). Female respondents and respondents who were concerned about land reform were less likely to enter the market. Rhino owners and respondents who owned more land were more likely to participate in the market. Respondents' income levels and trust in government were not significant determinants of the likelihood that they would participate in the market.

On average, rhino owners in our sample required a minimum payment of approximately ZAR 333,000 or $25,300/kg of horn to enter the legal horn trade if the market is regulated by a CSO managed by the DEA (Tab. 6). This mean reservation payment increased to a minimum of approximately ZAR 753,000 or $57,200/kg of horn for respondents who do not own rhinos (and presumably would incur substantial costs to acquire rhinos). Average reservation payments were lowest when the CSO was managed by WRSA. For rhino owners, the mean reservation payment when WRSA managed the CSO was less than ZAR 150,000 – the price at which experts estimated that rhino owners would be able to generate a small profit from selling horn.

3.4.2 Unregulated Market Logit Model Results

For the two Unregulated Market models, neither the market structure (auction or open trading) nor any of the minimum land requirements were significant determinants of participation in the market (Tab. 5). For the effects-coded model (AICc = 1,068.18), we again saw a pattern of increasing probability of participation as the payment per unit horn increased. For the continuous payment model (AICc = 1,069.59), there was a positive correlation between respondents' willingness to enter the legal market and the payment they would earn from selling rhino horn.

Positive attitudes towards horn trade and less trust in government were associated with an increased probability of participation in the unregulated market. Rhino owners were more likely to participate in the market and women were less likely to participate in the market.

The auction market structure was associated with higher mean reservation payments within our sample than the open trading market structure (Tab. 6). Rhino owners consistently required lower average reservation payments than other respondents. For both rhino owners and respondents who did not own rhinos (or preferred not to say if they own rhinos), the lowest mean reservation payment for rhino horn was associated with open trading and no minimum land requirement per rhino (~ZAR 105,300 or 2017 USD 8,000/kg for rhino owners; ~ZAR 417, 800 or 2017 USD 31,800 for non-owners).

4. Discussion

Our best-worst choice approach generated consistent and complementary results between the best-worst scaling and dichotomous choice experiment analyses. A CSO managed by Wildlife Ranching South Africa was preferred to one managed by the Department of Environmental Affairs. This is consistent with Davies-Mostert's (2014) observations that

ranchers distrust the government. We also note that distrust of the government increased the likelihood that respondents would participate in an unregulated market.

It is interesting to note that respondents displayed mixed opinions about De Beers managing the CSO. We assumed that since De Beers is a neutral, private organization that operates in the international diamond trade, respondents would prefer De Beers managing the CSO. However, the mean coefficient on CSO management by De Beers was not significantly different from zero in any model, although there was evidence of preference heterogeneity across respondents. This is interesting because it suggests that, among non-government entities, respondents preferred management by an industry organization with which they are familiar (WRSA), over an external, neutral organization (De Beers). If a CSO market structure is implemented, our results suggest it might be best managed by a wildlife-based organization that is trusted by members of the wildlife ranching industry to increase market participation and reduce the reservation payment required to incentivize participation.

We would like to note that there are both pros and cons associated with implementing a CSO market structure. Wildlife industry members, who tend to seek to avoid industry regulation (Davies-Mostert 2014), may not be supportive of a regulated market. They may be wary of participating in a market that grants a single organization the power to set prices and establish other regulations (e.g., minimum land requirements) related to their enterprise. However, pairing a fair and transparent CSO structure with horn-tracking technology (e.g., horn DNA databases and microchipping) would likely reduce illegally poached horn from entering the market (Biggs et al. 2013) and may help earn global support for legal international horn trade.

Within the Unregulated Market models, support for auctions and open trading markets were mixed. According to the BWS analysis, on average, an auction was preferred over open

trading – although there was heterogeneity of preferences across respondents. However, the DCE analysis showed that neither the auction nor open trading systems were significant determinants of market participation.

Across all models, respondents preferred higher horn payments. Payments of ZAR 15,000/kg of horn (approximately $1,000) and ZAR 50,000/kg of horn (approximately $4,000) were consistently considered too low (i.e., negative preference relative to the reference point and decreased likelihood of market entry) by respondents. There was no evidence of preference heterogeneity related to the payment per unit horn. Higher payments were always preferred. Our results suggest that payments greater than ZAR 150,000 or approximately $11,500/kg are necessary to increase the probability of market entry (in particular by individuals who are not currently rhino owners), which is an important finding in a CSO market structure where prices are set.

Rhino owners consistently required lower reservation payments than other respondents to enter legal trade. This is likely because rhino owners have already substantially invested in procuring rhinos and in rhino-related security and management. Other respondents, however, may not have made those investments, and thus they require a considerably higher payment to enter the market. This is important when considering the effects of legalizing horn trade on rhino conservation—significantly higher payments are needed to convince individuals who do not currently own rhinos to acquire rhinos and to manage their lands for rhinos. As an interesting extreme case, in a market where the DEA manages a CSO, a subset of respondents who did not own rhinos required reservation payments that approached or exceeded the estimated black market price (approximately ZAR 912,000 or $65,000/kg; Hubschle 2016). Across both rhino owners and non-rhino owners, the lowest reservation payments were associated with open

trading and a CSO managed by WRSA – indicating that respondents prefer markets that are not government regulated.

Minimum land size requirements per rhino were rarely significant in any model, which was surprising because one might expect that more stringent land requirements would reduce respondents' utility from entering the horn trade and/or would increase reservation payments for horn. For the unregulated market RPL models, respondents preferred the minimum land requirement of 100ha/rhino. In contrast, for the CSO RPL models (which would provide an external entity with control over the price of rhino horn) there was evidence of preference heterogeneity with regards to the 100 ha/rhino land requirement. This result suggests that respondents may be more willing to accept a minimum land requirement if they are not also required to comply with centralized control of rhino horn trade.

Our findings also suggest mixed opinions across respondents about intensive versus extensive rhino management. Informal conversations with respondents indicated that some respondents may be more accepting of the idea that horn trade legalization may lead to intensive rhino farming (i.e., they may accept or even prefer a policy with no minimum land requirement), whereas others wanted legalization to result in substantial habitat conservation (by requiring large minimum land areas). Because of concerns that horn trade legalization may lead to intensive rhino farming (see Wright et al. 2016), we suggest further exploration of preferences towards minimum land requirements or other policy tools that can be used to link the supply of rhino horn with conservation outcomes.

Although we specifically focused our survey on legal international trade in horn, these results are also likely applicable to South Africa's newly legalized domestic horn trade. While the first horn sale in South Africa in 2017 occurred through a private auction (Du Toit 2017), the

Private Rhino Owners Association of South Africa (which is part of WRSA) is also exploring the establishment of a CSO to handle future trade (Jones 2017).

A limitation of this study is the small sample size used for analysis, although van der Waal and Dekker (2000) had comparable response rates for their mail-based and industry newsletter surveys to wildlife ranchers. There are documented challenges associated with surveying wildlife ranchers in South Africa, particularly about rhino-related topics. Wildlife ranchers tend to distrust scientists and are unwilling to participate in research due to fears of increased industry regulation (Davies-Mostert 2014). While we note the limitations of this study, we obtained interesting initial insights that may be used to inform future research efforts.

5. Conclusions

To the best of our knowledge, this is the first study to explore the market preferences of potential supply-side stakeholders in the legal international trade in rhino horn. This research is particularly timely given the recent reversal of the national moratorium on domestic rhino horn trade in South Africa. Our results show that market attributes, such as market structure and the payment per unit of horn, affect wildlife industry members' willingness to participate in the trade in rhino horn, as do their opinions about government and attitudes towards trade. If supply-side market-based measures are to be used to supplement regulations and interventions to reduce the demand for illegally-sourced rhino horn, then our findings suggest that these interventions are more likely to succeed if the market is not regulated by a government organization that industry members distrust.

Based on our findings, reservation payments would be most competitive under an open trading market structure or when a central selling organization is managed by the wildlife

ranching industry. Whether legalizing the global rhino horn trade would provide the necessary financial incentives for wildlife industry members to engage in legal trade would depend on whether the price at which horn may be sold is sufficient to offset the substantial costs of investing in, managing and protecting rhinos. We found that the reservation payments for respondents who do not currently own rhinos are substantially higher than those for rhino owners. If the Asian markets to which the horn is sold colluded to keep prices low then trade might not provide the necessary financial incentives to increase rhino populations on private lands.

We also note that our results were inconclusive about whether market participants would support efforts to tie rhino horn trade to conservation outcomes in the form of maintaining extensive lands, rather than intensively farming rhinos. Our findings do not provide clear insights as to whether legalizing the global rhino horn trade would result in rhino conservation in terms of both increased rhino populations on private lands and management of these rhinos on extensive areas of land. More research is required to determine whether rhino horn trade may be used to incentivize conservation of rhinos on extensive private properties, and how much land should be allocated per rhino (depending on habitat type and other ecological considerations).

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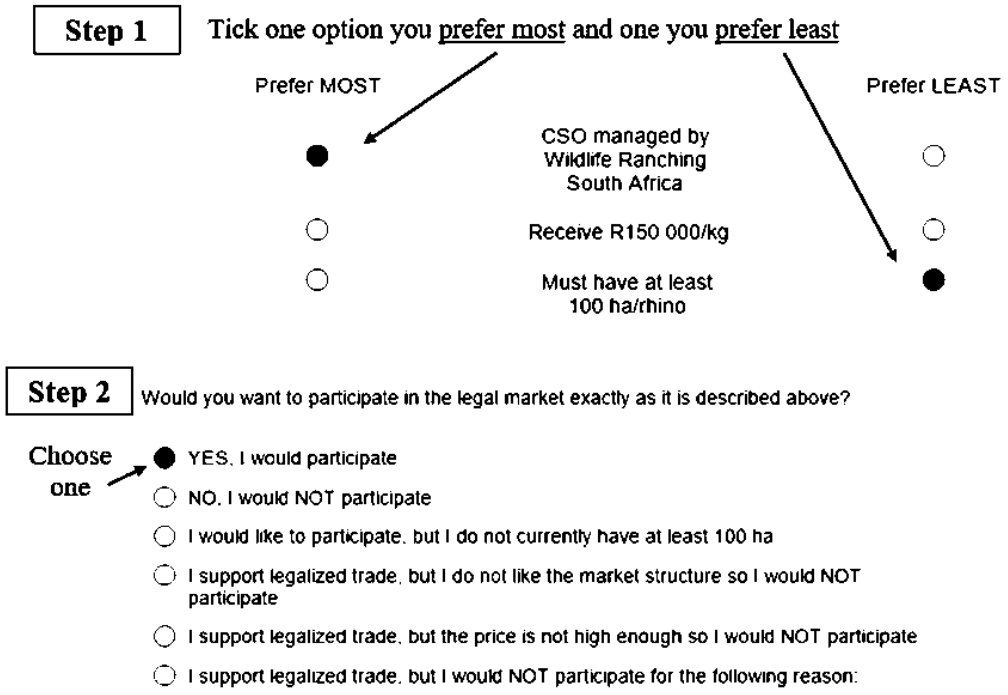

Figure 1. Example of a BWC policy scenario.

Table 1. Effects coding for choice experiment attributes and levels.

Attribute/Level	Effects Coding[a]			
Central selling organization (CSO):	De Beers	WRSA		
Department of Environmental Affairs (DEA)	-1	-1		
De Beers	1	0		
Wildlife Ranching South Africa (WRSA)	0	1		
Unregulated market structure:	Open trading			
Auction	-1			
Open trading	1			
Rhino horn payment (ZAR/kg):	50,000	150,000	300,000	500,000
15,000 (~$1,000, 2017 USD)	-1	-1	-1	-1
50,000 (~$4,000)	1	0	0	0
150,000 (~$11,500)	0	1	0	0
300,000 (~$23,000)	0	0	1	0
500,000 (~$38,000)	0	0	0	1
Minimum land requirement (ha/rhino):	50	100		
None	-1	-1		
50	1	0		
100	0	1		

[a] For each choice experiment, attribute levels take a value of 0 if the attribute level is not included in the experiment (i.e. is absent from the experiment), 1 if the attribute level is included in the choice experiment, or -1 if the base level is included in the experiment.

Table 2. Explanatory variables included in regression analysis.

Explanatory Variable	Description	Coding
Gender	Gender of respondent	0: male 1: female
Income (ZAR million)	Pre-tax income of respondent	1: ≤ ZAR 1,000,000 1.5: ZAR 1,000,001 – ZAR 2,000,000 2.5: ZAR 2,000,001 – ZAR 3,000,000 3.5: ZAR 3,000,001 – ZAR 4,000,000 4.5: ZAR 4,000,001 – ZAR 5,000,000 5.5: ZAR 5,000,001 – ZAR 6,000,000 6.5: ZAR 6,000,001 – ZAR 7,000,000 7: >ZAR 7,000,000
Amount of land (ha)	Total amount of land respondent owns, leases, or manages (ha)	0: None 100: <100 ha 300: 100 ha – 500 ha 750: 501 ha – 1,000 ha 1500: 1,001 ha – 2,000 ha 2500: 2,001 ha – 3,000 ha 3500: 3,001 ha – 4,000 ha 4500: 4,001 ha – 5,000 ha 5000: >5,000 ha
Rhino ownership	Rhino ownership status of respondents	0: respondent does not currently own rhinos 0: respondent preferred not to disclose whether s/he owns rhinos 1: respondent currently owns rhinos
Attitude towards horn trade	Respondent's attitude towards legalization of the rhino horn trade	Score generated using principal factor analysis: higher values reflect more positive attitudes towards legalization of the trade
Concern about land reform	Respondent's concern regarding land reform/restitution (not at all to very concerned)	Not at all concerned – dummy variable Slightly concerned – dummy variable Moderately concerned – dummy variable
Distrust of government	Respondent's belief that interactions with the government increases poaching risks	Score generated using principal factor analysis: higher values reflect more negative attitudes towards government (i.e., higher risk concern and lower trust in government)

Table 3. Sociodemographic and attitudinal characteristics of respondents.

Characteristic	Percent of sample	Characteristic	Percent of sample
Gender:		Income:	
Male	95	≤ ZAR 1,000,000	25
Female	5	ZAR 1,000,001 – ZAR 2,000,000	23
		ZAR 2,000,001 – ZAR 3,000,000	10
Age:		ZAR 3,000,001 – ZAR 4,000,000	8
18 – 25 years	1	ZAR 4,000,001 – ZAR 5,000,000	4
26 – 35 years	10	ZAR 5,000,001 – ZAR 6,000,000	6
36 – 45 years	28	ZAR 6,000,001 – ZAR 7,000,000	4
46 – 55 years	35	> ZAR 7,000,000	20
56 – 65 years	18		
66 – 75 years	8	Amount of land:	
≥ 76 years	1	No land	9
		< 100 ha	2
Rhino ownership:		100 – 500 ha	5
Yes	20	501 – 1,000 ha	7
No	66	1,001 – 2,000 ha	18
Prefer not to say	14	2,001 – 3,000 ha	11
		3,001 – 4,000 ha	11
Concern about land reform:		4,001 – 5,000 ha	4
Not at all concerned	6	> 5,000 ha	32
Slightly concerned	8		
Moderately concerned	21		
Very concerned	65		

Characteristic	Mean	Std Dev	Minimum	Maximum
Attitude towards horn trade	14.64	1.63	3.15	15.74
Distrust of government	7.75	1.80	1.86	11.15

Table 4. Best-worst scaling task: random parameters logit model results.

	Central Selling Organization (CSO)				Unregulated Market			
	Mean Coefficient		St. Dev. Coefficient		Mean Coefficient		St. Dev. Coefficient	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Attribute impacts:								
Market structure:								
CSO	-0.244**	0.111	0.977***	0.132				
Unregulated market					0.890***	0.072	0.273**	0.114
Rhino horn payment	0.672***	0.097	0.747***	0.132	0.441***	0.065	0.267**	0.119
Minimum land requirement	0				0			
Level scale values:								
Market structure:								
CSO managed by DEA[a]	-1.876							
CSO managed by De Beers	0.037	0.140	1.266***	0.168				
CSO managed by WRSA	1.840***	0.169	1.196***	0.220				
Auction					0.266			
Open trading					-0.266***	0.061	0.401***	0.092
Rhino horn payment (ZAR `000/kg):								
15[a]	-1.456				-1.175			
50	-0.519***	0.130	0.078	0.158	-0.349***	0.100	0.055	0.220
150	0.190	0.124	0.176	0.179	0.010	0.099	0.041	0.181
300	0.545***	0.131	0.157	0.322	0.658***	0.110	0.200	0.284
500	1.241***	0.179	0.350	0.490	0.857***	0.121	0.261	0.260
Minimum land requirement (ha/rhino):								
None[a]	-0.149				-0.114			
50	-0.067	0.093	0.222	0.174	-0.101	0.074	0.182	0.221
100	0.216*	0.121	0.913***	0.141	0.215***	0.079	0.035	0.180
Log likelihood	-1,244.694				-1,301.052			

Asterisks denote significance: (***) at the 1% level, (**) 5% level, and (*) 10% level

[a] Effects coded: coefficient calculated using the negative sum of the level scale values corresponding to this attribute.

Table 5. Dichotomous choice task: logit model results.

	Central Selling Organization (CSO)				Unregulated Market			
	Continuous Payment		Effects-Coded Payment		Continuous Payment		Effects-Coded Payment	
	Coeff.	**S.E.**	**Coeff.**	**S.E.**	**Coeff.**	**S.E.**	**Coeff.**	**S.E.**
Constant	-7.967***	1.075	-7.530***	1.063	-6.843***	0.961	-6.366***	0.953
Market structure:								
CSO managed by DEA[a]	-0.343		-0.178					
CSO managed by De Beers	-0.026	0.117	-0.111	0.142				
CSO managed by WRSA	0.369***	0.107	0.290**	0.113				
Auction					-0.028		-0.046	
Open trading					0.028	0.078	0.046	0.080
Rhino horn payment (ZAR `000/kg):								
15[a]			-0.761				-0.812	
50			-0.283	0.179			-0.344**	0.166
150			0.090	0.176			0.269*	0.162
300			0.492***	0.183			0.303*	0.160
500			0.462**	0.184			0.585***	0.162
Continuous bid (15 – 500)	0.002***	<0.001			0.002***	<0.001		
Minimum land requirement (ha/rhino):								
None[a]	-0.020		-0.045		0.065		-0.032	
50	-0.005	0.107	-0.076	0.113	-0.078	0.103	-0.079	0.112
100	0.025	0.117	0.120	0.142	0.013	0.119	0.111	0.143
Respondent characteristics:								
Gender	-1.364***	0.442	-1.365***	0.443	-0.798**	0.381	-0.801**	0.382
Income (ZAR million)	0.014	0.037	0.014	0.037	0.034	0.035	0.034	0.035
Amount of land (ha)	0.0001***	<0.001	0.0001***	<0.001	0.0001	<0.001	0.0001	<0.001
Rhino ownership (dummy variable)	0.583***	0.210	0.596***	0.211	0.527***	0.204	0.534***	0.205
Attitude towards horn trade	0.426***	0.069	0.428***	0.069	0.327***	0.062	0.326***	0.062
Concern about land reform								
Not at all concerned	0.638*	0.343	0.615*	0.342	0.511	0.325	0.516	0.328
Slightly concerned	0.232	0.282	0.218	0.283	0.480*	0.271	0.486*	0.273
Moderately concerned	-0.433**	0.202	-0.455**	0.203	-0.120	0.191	-0.126	0.192
Distrust of government	0.020	0.045	0.021	0.046	0.104**	0.044	0.103**	0.044
Log likelihood	-485.075		-482.067		-518.465		-513.581	

Asterisks denote significance: (***) at the 1% level, (**) 5% level, and (*) 10% level

[a] Effects coded: negative sum of the below level scale values corresponding to this attribute.

Table 6. Mean reservation payments/kg by market structure and rhino ownership (in thousands of ZAR, where ZAR 100,000 ≈ $7,600 2017 USD).

	Respondent owns rhinos			Respondent does not own rhinos or prefers not to say if they own rhinos		
	Minimum land requirement			Minimum land requirement		
	None	50 ha/rhino	100 ha/rhino	None	50 ha/rhino	100 ha/rhino
All respondents:						
Central selling organization (CSO) managed by:						
Department of Environmental Affairs (DEA)	351.95	345.47	332.92	773.50	766.60	753.23
De Beers	228.41	223.18	213.05	630.98	624.08	610.71
Wildlife Ranching South Africa (WRSA)	122.87	120.57	116.11	454.72	448.17	435.51
Unregulated market structure:						
Auction	116.26	154.82	128.21	441.78	503.53	463.98
Open trading	105.30	137.47	124.23	417.78	479.15	457.37
Male respondents (95% of all respondents):						
Central selling organization (CSO) managed by:						
Department of Environmental Affairs (DEA)	306.86	300.40	287.90	754.88	747.97	734.61
De Beers	184.53	179.41	169.50	612.36	605.46	592.09
Wildlife Ranching South Africa (WRSA)	83.67	81.67	77.79	436.18	429.65	417.02
Unregulated market structure:						
Auction	83.28	120.30	94.55	432.64	494.37	454.84
Open trading	73.20	103.42	90.74	408.67	470.00	448.23