Conserving rhinos by legal trade: Insights from a choice experiment with rhino horn consumers

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ABSTRACT

A legal rhino horn trade is suggested in order to reduce poaching. To examine the implications of this proposition, we conducted a choice experiment with 345 rhino horn consumers in Vietnam, investigating their preferences for legality, source, price and peer experience of medicinal efficacy as attributes in their decision to purchase rhino horn. We calculated consumers' willingness to pay for each attribute level. Consumers preferred and were willing to pay more for wild than semi-wild and farmed rhino horn but showed the strongest preference for legal horn, although higher-income consumers were less concerned about legality. The number of peers having used rhino horn without positive effect reduced preference for wild-sourced horn and increased preference for legality. Our results suggest that a legal trade in rhino horn would likely continue to face competition from a parallel black market. Whether poaching would be reduced depends on the legal supply of wild and semi-wild horns, campaigns ability to change consumer preferences, and regulation efforts.

1. Introduction

The past decade, nearly 10,000 rhinoceros (henceforth rhinos) were killed by poachers in Africa. The remaining rhino populations are steadily declining, with less than 30,000 animals left in 2020 (Save the Rhino International, 2020). Considerable effort has been invested in campaigns to reduce the demand for rhino horns (Olmedo et al., 2018), but many of these campaigns are criticised for lack of insights into their target audience (Dang and Nielsen, 2021a, 2018; Dang et al., 2020; Greenfield and Veríssimo, 2019; Margulies et al., 2019). Reducing demand for rhino horn and other illegal wildlife products requires understanding the determinants of demand and consumers' decision-making process (Nielsen and Jacobsen, 2020; Veríssimo et al., 2020; Veríssimo and Wan, 2019; Dang and Nielsen, 2018). An open question is also how elastic rhino horn demand is to price changes (Eikelboom et al., 2020; Nadal and Aguayo, 2014). In Vietnam, most rhino horn consumers purchase a small piece of rhino horn (often 100 g) that is used over a long period, ground into a powder. The powder is mixed with water and shared with business associates in parties to strengthen relationships or taken as a treatment for hangover and for body detoxification afterwards (Dang and Nielsen, 2018; Truong et al., 2015). Based on interviews with 50 rhino horn consumers, Dang et al. (2020) found that the intention to purchase and/or use rhino horn is influenced most by individuals in the potential consumers' direct networks, who had experience using this product (i.e., peer users).

In some rhino range states, notably South Africa, rhinos are routinely dehorned to discourage poaching, and this has led to growing stockpiles of horn that has been proposed could be sold in a legal trade to reduce poaching. However, the outcome of a legal international trade in rhino horn remains controversial (Cheung et al., 2021a, 2018; Crookes, 2017; Nadal and Aguayo, 2014; Biggs et al., 2013; Child, 2012). Proponents argue that the sale of sustainably harvested and stockpiled horns could meet consumer demand, generate income to fund anti-poaching activities, create jobs for local communities, discourage poachers and encourage private rhino owners to conserve rhinos (RhinoAlive, 2021; Biggs et al., 2013; Child, 2012). A legal trade also received support from a majority of traditional Chinese medicine practitioners interviewed in Hong Kong (Cheung et al., 2018) and in the Chinese province of Guangdong (Cheung et al., 2021a). Yet, very little evidence is available on consumer preferences for a legal trade (Nadal and Aguayo, 2014), and existing studies provided contradicting predictions on its likely outcome (Dang and Nielsen, 2018; Hanley et al., 2017).

Current stockpiles of mainly white rhino horn appear to be substantial and are supplied from rhino populations that cover a continuum of management practices, from wild to 'farmed' (Taylor et al., 2017). While most white rhinos are considered wild, many subpopulations live on extensive or semi-extensively managed privately-owned ranchlands and some subpopulations in semi-intensive or intensively managed environments (Emslie and Adcock, 2016). White rhinos living in an extensive, semi-extensive or semi-intensively managed environment

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generally have higher growth rates than captive-bred rhinos (Swaisgood et al., 2006) and may support conservation of wild populations as a supplementary source (Emslie and Adcock, 2016). Some private owners keep their rhinos in more intensively managed semi-wild environments providing supplemental feeding, water, and veterinary care (Stoddard, 2019). Notably, the term 'farmed' rhino could be misunderstood and confused with 'captive-breeding'. However, there is very limited intensive rhino management that meets the generally recognised description of 'farming' and almost all rhinos in Africa are regarded as at least 'semi-wild' (Emslie, 2020).

Privately-owned white rhinos are envisioned as the primary source of horns in the proposed legal trade (Taylor et al., 2017). At the beginning of 2020, nearly 50% of all white rhinos in South Africa were in private game reserves (Ferreira and Dziba, 2021). However, private rhino owners are facing increasing costs of security measures, which may cause them to give up (Balfour et al., 2019; Emslie et al., 2019; Minnaar and Herbig, 2018; Ferreira et al., 2014). The Covid-19 pandemic preventing tourism further poses a tremendous financial challenge to the operation of rhino farms (Clements et al., 2020). It has been suggested that rhino owners may be increasingly willing to participate in the legal-horn trade to offset these costs (Chapman and White, 2020; Clements et al., 2020; Rubino and Pienaar, 2018; Wright et al., 2018). Although the domestic trade ban in South Africa ended in 2017 (Jones, 2017), revenue from rhino horn sales is minimal due to the exclusion of international buyers who could pay higher prices (Emslie et al., 2019).

Here we aim to assess preferences and trade-offs among own-reported consumers and intended rhino horn consumers. We investigate their choice to purchase rhino horn, including in a context of a legal trade, providing insights for the design of rhino horn demand reduction strategies and assessing the likely outcome of a legal rhino horn trade. Specifically, we interviewed these consumers and implemented a choice experiment to assess their preferences for different attributes of this good, including its source, purported efficacy, legality, and price. We compared the effect of the attributes in scenarios calculating Willingness To Pay (WTP). Moreover, we tested the effect of consumer socio-demographic characteristics by including interactions in the model to explore further what changes most effectively will reduce demand for rhino horn and its implications for a legal trade.

2. Methods

2.1. Study areas

Vietnam and China are considered the two largest markets for rhino horn (Eikelboom et al., 2020). We conducted the study in Hanoi, the capital of Vietnam and the second-largest city by population (General Statistics Office of Vietnam [GSOV], 2019), identified as a hotspot for rhino horn trade and consumption. As of 2019, GDP per capita in larger Hanoi was estimated at VND 6.34 million per month (approx. US$270) (GSOV, 2019). Luxury wildlife products are popular among the affluent class in Hanoi (Drury, 2011). Rhino horn trafficked from Africa is supplied to both local consumers and Chinese tourists visiting the city (Crosta et al., 2017). This study focuses on local consumers.

2.2. Choice experiment and questionnaire design

The choice experiment and this study focused on the use of rhino horn as a powder for body detoxification, to cure hangovers and for sharing as a source of prestige (cf. above). To design the choice experiment, we adopted a mixed-methods approach combining literature review, key informant interviews, focus group discussions, and pilot tests. First, we reviewed the relevant literature and conducted semi-structured interviews with representatives from Vietnam's CITES Management Authority, conservation organisations working in Hanoi, researchers, and experts working with rhino horn issues to develop a list of attributes

affecting the choice of consuming rhino horn. Then we discussed this list with focus group participants consisting of rhino horn users, intended users, and people with a history of trading rhino horn. Six focus groups with 3–5 participants were conducted between June and July 2019. The final list includes four attributes: source of the horn, peer reference, legality of the horn, and the price per 100 g horn in million Vietnamese Dong (VND) (see Table 1).

The combinations of the attributes and their levels produced 36 alternatives. We used priors from Hanley et al. (2017) to make a d-efficient design in the software NGENE. The design included 12 choice sets, which were distributed into two blocks so that each block contained six choice sets. The choice sets were transformed into choice cards. Each choice card included two scenarios with conditions for buying rhino horn and a "Do not buy" option. All attributes varied across alternatives except peer reference. The peer reference attribute with three levels was fixed within blocks in order to reduce the cognitive burden on respondents. We pilot tested the design on a sample of 30 respondents. Data from the pilot test was used to estimate a multinomial logit model (MNL). We used the priors from this model to update the design combinations but kept the original basic structure. Illustrative pictures were included in the choice cards to depict attributes and differentiate between their levels to reduce the cognitive burden on the respondents (see Appendix A, Supplementary materials for an example of a choice card).

Each respondent received two different blocks, each consisting of six choice sets. The number and order of peers and blocks were varied systematically to avoid ordering effects and ensure the possibility of estimating independent effects (Appendix B, Supplementary materials). Respondents were randomly subjected to one of these. Implementing the questionnaires included an introduction script describing the objectives of the study; signing an informed consent form; structured questions about the respondents' behaviours, beliefs, knowledge; a short video and the choice experiment including a description of the scenarios (i.e., with respect to the peer reference levels), the attributes and their levels to ensure that respondents received identical information from research assistants (see Appendix C, Supplementary materials). A cheap talk script was integrated into the introduction to minimize bias originating from the hypothetical nature of the choice experiment (Tonsor and Shupp, 2011). Furthermore, respondents were reminded of the associated cost, benefits, and risks of their choices, including their budget constraints. Follow-up questions were included to identify free-riders and irrational respondents who did not strive to maximize utilities. Before completing the choice task, respondents were shown a short video about the farming and dehorning of rhinos to illustrate the possibility of sustainable and humane rhino horn production and to ensure a common frame of reference. Care was taken to frame it neutrally to avoid bias. Respondents were then asked to rate the importance of each attribute of their choices (incl. Source, peers, legality, and price) on a four-point Likert scale (1 = not important, 4 = extremely important). The questionnaire ended with questions about socio-demographic status, including whether anyone in the respondents' families was perceived as urgently needing rhino horn for medical purposes.

2.3. Data collection

The choice experiment was conducted with respondents selected among participants of previous studies (Dang et al., 2020; Dang and Nielsen, 2018; Truong et al., 2015), who had consumed rhino horn at least once (henceforth consumers) and intended consumers who had not yet consumed but expressed intention to purchase rhino horn in the near future (henceforth intenders). We approached respondents with available contact details. We used snowballing to identify additional respondents through the personal networks of the principal author and seven research assistants, expanding the initial sample to 347 consumers. Hence, we cannot calculate a response rate. Data collection was undertaken over four months, from January to April 2020. Interviews,

Table 1

Attributes, their levels, and hypotheses.

Attribute	Description	Level	Hypotheses
Source[1]	Horn from a wild, semi-wild, or farmed rhinos.	Wild, semi-wild, farmed[2]	1. Consumers prefer wild over farmed rhino horn.
Peer reference[3]	Peer experience with rhino horn as the number of peers (out of 10) having used this product with negative or no effect.	0, 5, 10	2. The number of peers having experienced no or a negative effect of rhino horn reduces demand for rhino horn.
Legality	Legality of the rhino horn.	Legal, illegal[2]	3. Consumers prefer horns supplied through a legal trade.
Price	Price per 100 g in million VND.	40, 50, 60, 70, 80, 90	4. The direct price elasticity of demand for rhino horn is elastic.

Notes: 1. Wild rhinos are defined as those living in their natural habitats (incl. Grasslands and floodplains, in government-controlled reserves or parks) and finding food and water themselves. Semi-wild rhinos are those living in the semi-wild environment of private ranches. They also need to find food and water themselves but receive supplemental feeding at some times of the year (e.g., drought). Farmed rhinos are conceived as bred in small enclosures and mainly fed by humans and thus do not need to find food and water themselves. These categories are defined solely for the purpose of this choice experiment to capture the two extremes and may not represent the reality of contemporary rhino management.

2. The reference attribute levels are farmed and illegal, and dummies for these are not included in the models.

3. The peer reference attribute was fixed within blocks.

including the choice experiment, lasted 20–30 min and were conducted face to face at a secure location of the respondents' choice (see Dang, 2021).

2.4. Data analysis

Choice experiments take departure in random utility theory (McFadden, 1974), which posits that an individual when making choices, chooses the alternative that yields the highest level of utility (i. e., individual benefit) and that utility is observed with an error. The level of utility is determined by the attribute levels in the chosen alternative plus a random and unobservable component. We implemented both random parameter logit (RPL) and latent class (LC) models, with and without interactions with socio-demographic variables and other covariates. The RPL model takes preference heterogeneity into account and has the advantage of computational flexibility. The RPL model also helps relax the Independence of Irrelevant Alternatives (IIA) assumption of the multinomial logit model, which is often inappropriate (Train, 2009). We estimated the RPL model with 1000 Halton draws. According to Train (2009), the RPL model can be specified in terms of the probability that individual n chooses alternative i as the integral of the conditional logit probabilities over a density of parameters:

$$P_{ni} = \int \left[\left(exp(\beta'_n X_{ni}) \middle/ \sum_j exp(\beta'_n X_{nj}) \right) \right] f(\beta) d\beta \tag{1}$$

where P_{ni} is the choice probability under the RPL model, β_n' is a vector of parameters for the vector of attributes X_{ni} of the j'th alternative presented to the respondent, and $f(\beta)$ is a distributing function of β with an assumed distribution.

We added explanatory variables (e.g., socio-demographics, behaviours, and beliefs) to the model by creating interaction terms with the attributes. We assumed that all attributes follow a normal distribution, except for price, which was log-normally distributed to avoid theoretical inconsistencies of positive preferences for price. We included an Alternative Specific Constant (ASC) to the model, which takes the value of one for the "Do not buy" option and zero otherwise. The ASC captures preferences for not buying regardless of the attribute levels in the two other alternatives. The utility function in our analysis is specified as follows:

$$U = \beta_{ASC} * ASC + \beta_{wild} * wild + \beta_{semiwild} * semiwild + \beta_{legal} * legal + \beta_{price} * price + \varepsilon \tag{2}$$

The LC model accommodates preference heterogeneity by grouping individuals into latent classes within which preferences are assumed identical (Hess, 2014). We followed Henscher et al. (2015) in estimating the direct price elasticity of demand for rhino horn, which is the percentage change in the probability of choosing a particular alternative in

the choice set given one percentage change in the price of that alternative (Train, 2009). We used estimated parameters from the model without interaction terms for elasticity calculations. We followed Mariel et al. (2021) using the following equation to estimate the marginal Willingness To Pay (WTP):

$$WTP = \frac{\beta_{attribute}}{exp(\mu + \sigma^2/2)} \tag{3}$$

which is the price that consumers are willing to pay for 100 g of rhino horn with a particular attribute level, holding other attribute levels constant. $\beta_{attribute}$ is the estimated parameters of the attribute level, μ and σ are the mean and standard deviation of the price parameter β_{price}. We estimated standard errors by the Delta method (Hess and Palma, 2019, p. 27). We first estimated the marginal WTP from the model without interaction terms assuming that respondents made their choices based on the attribute levels presented in the choice cards only. Then we estimated the marginal WTP under the effect of peer reference, which was specified in the choice experiment as the number of peers having used rhino horn with negative or no effect. As we aimed to analyse the response of consumers' choice to peer reference, we interacted peer reference with the three other attributes in the model. We allowed for heterogeneity on all attributes except the number of peer referents, which was fixed to estimate its marginal effect on other attributes. We included confounding variables (incl. Socio-demographics, behaviours, beliefs, knowledge, attitude) one at a time through interaction with the attribute levels to examine their influence on consumers' choice. The analysis was conducted using the Apollo package (Hess and Palma, 2019) in RStudio version 1.2.5042.

An ethical review of this study was conducted, and ethical clearance was received from the Research Ethics Committee for SCIENCE and SUND at the University of Copenhagen (Ref. 504-0069/19-5000) and the Ethical Review Board at the Hanoi University of Public Health (Ref. 461/2019/YTCC-HD3). The study team complied with all policies and procedures of the authorising Ethical Review Boards, European and national legislation in the two countries, and fundamental ethical principles. Given the sensitive nature of using rhino horn, a strict policy of informed consent was followed. Potential respondents were informed of the study purposes, potential benefits and risks of being enrolled in the study and that they could withdraw from the interview at any point in time. We employed real-time data entry through password protected tablets uploading to an encrypted cloud, the security of which was handled by the University of Copenhagen's IT department. This helped eliminate the possibility of theft or loss of hardcopy questionnaires, potentially enabling others to gain insight into incriminating and personal data.

3. Results

Two respondents consistently not participating in the choice experiment were excluded leaving a final sample of 345 respondents, including 220 rhino horn consumers and 125 intenders. There was no significant difference between consumers and intenders in knowledge about legal sanctions for having rhino horn (H = 2.8; P = 0.24). Only 23 (6.7%) admitted to knowing that storing more than 50 g of rhino horn is illegal, according to the Vietnamese penal code. Mean age was 49 and the median 48, and there was no significant difference between consumers and intenders, or between males and females. Average monthly income was in the range of VND50–59 million (approx. US$2100-2800), much higher than the national average of VND3.76 million (approx. US $176) in 2018 (GSOV, 2019). The occupation of rhino horn consumers and intenders differed significantly (Appendix D, Supplementary materials). Rhino horn consumers were more likely to be government officials, investors, and business owners, while intenders were more likely to be white-collar workers, doctors, and teachers (F = 4.5; P < 0.01). The most common uses of rhino horn were for reducing hangover (66.8%) and body detoxification (58.2%) (multiple answers allowed). A sizeable proportion used rhino horn powder for general health benefits (19.5%) and for reducing high fever (13.2%). Only 20% of consumers admitted purchasing rhino horn themselves, while the rest stated having received rhino horn as a gift, including being offered it at parties (Appendix E, Supplementary materials).

3.1. Consumer preferences

A total of 4140 choice observations were made, of which 17.7% represented the "Do not buy option." We present three RPL models for the choice experiment in Table 2, which indicate considerable heterogeneity in consumer preferences. Model 1 contained only the non-fixed attributes (i.e., without interactions with peers' experience about efficacy). Model 2 included interactions with the fixed attribute peers. We also estimated several RPL models with and without interactions between attribute levels and covariates. Model 3, allowing correlations between all attribute levels and adding interaction terms with income and nrh (i.e., the urgency of using rhino horn), provided the best fit of these models, judged by the AIC/n criterion (AIC = 4493.19). There was no significant difference between the ASC for the two alternatives in the choice set, and since they are structurally identical in nature, we used one ASC in each model. The coefficient for the ASC, which captures respondent preferences for the "Do not buy option", was negative and significant in all three models, suggesting that respondents preferred to buy rhino horn over the "Do not buy option". Respondents preferred wild over semi-wild or farmed horns and legal over illegal horns in all three models. As expected, the effect of price was negative. Including the socio-demographic covariates in Model 3 revealed that income had a significant positive modifying effect increasing preferences for wild and semi-wild over farmed rhino horn. Income also reduced the negative effect of price, revealing that higher-income respondents were less price

Table 2
Estimation results for RPL and LC models with socio-demographic covariates (Standard errors of the estimates are provided in parentheses).

	RPL			LC		
	Model 1	Model 2	Model 3		Model 4	
	No interactions	Interaction with peers	Interaction with peers, inc, nrh	Class 1	Class 2	Class 3
ASC	−4.137*** (0.345)	−4.917*** (0.394)	−4.646*** (0.385)	−2.798*** (0.151)		
Wild	3.905*** (0.249)	5.905*** (0.432)	2.509*** (0.651)	0.439*** (0.238)	0.781*** (0.153)	5.423*** (0.265)
Semi-wild	2.604*** (0.146)	3.523*** (0.257)	2.442*** (0.399)	2.302*** (0.316)	0.839*** (0.148)	2.990*** (0.163)
Legal	3.977*** (0.303)	5.518*** (0.434)	5.656*** (0.666)	6.259*** (0.408)	1.521*** (0.119)	1.070*** (0.139)
Price	−2.630*** (0.057)	−2.637*** (0.080)	−2.356*** (0.115)	−0.084*** (0.006)	−0.078*** (0.003)	−0.047*** (0.003)
Wild × peers		−0.214*** (0.045)	−0.193*** (0.045)			
Semi-wild × peers		−0.108*** (0.033)	−0.105*** (0.034)			
Legal × peers		−0.114*** (0.035)	−0.107*** (0.036)			
Price × peers		−0.002*** (0.006)	−0.002*** (0.001)			
Wild × income			0.363*** (0.082)			
Semi-wild × income			0.121*** (0.049)			
Legal x income			−0.023 (0.080)			
Price x income			0.004*** (0.001)			
Wild x nrh			2.474*** (0.500)			
Semi-wild x nrh			1.063*** (0.320)			
Legal x nrh			0.841 (0.607)			
Price x nrh			−0.010 (0.008)			
Sd.ASC	−4.001*** (0.314)	5.033*** (0.508)	−5.030*** (0.396)			
Sd.wild	−3.149*** (0.283)	3.801*** (0.332)	−3.726*** (0.350)			
Sd.semi-wild	1.005*** (0.183)	−1.486*** (0.192)	1.354*** (0.217)			
Sd.legal	3.592*** (0.279)	−4.732*** (0.350)	−4.312*** (0.297)			
Sd.price	0.592*** (0.035)	−0.698*** (0.039)	0.513*** (0.050)			
Pr(class)				0.29	0.31	0.40
Pr(class) x income				−0.028 (0.043)	−0.310*** (0.057)	
Pr(class) x nrh				−0.611** (0.277)	−1.247*** 0.331)	
No. of choice sets/ respondents	4140/345	4140/345	4140/345	4140/345		
Pseudo R²	0.480	0.501	0.510	0.510		
LogLik	−2356.11	−2253.58	−2224.60	−2225.411		
AIC	4732.22	4535.16	4493.19	4488.82		
BIC	4795.50	4623.76	4632.42	4609.06		

Notes
1. ***, **, * indicate significance at 1%, 5%, 10% level.
2. The dummy nrh reflects whether anyone in the respondents family currently needs rhino horn for health-related purposes.

sensitive, although the absolute effect was small. The interaction between income and legality was insignificant, indicating that higher-income respondents paid neither more nor less attention to the legality of the horn. Higher urgency for using rhino horn (nrh) also increased the preference for wild-sourced products but had no significant modifying effect on price sensitivity or attention to legality.

To investigate further if the effect of covariates were more pronounced for some respondents than others, we estimated an LC model, where class membership probabilities were determined by income and the urgency of using rhino horn. A model with three classes was selected based on the AIC/n criterion (Model 4). Most respondents fell in Class 3 (40%), characterized by higher income and more likely being in need of rhino horn for treating health-related problems. Members of Class 1 (29%) and Class 2 (31%) were more likely to have lower incomes and less likely to be in urgent need of rhino horn. All three classes generally preferred wild-sourced over farmed horns. Class 3 members also preferred wild over semi-wild horns, whereas Class 1 and Class 2 preferred semi-wild over wild horns. Notably, the preference for legality differed between classes. Class 1 had the strongest preference for legal horns, while Class 3 was the lowest. Class 3 was furthermore less sensitive to price than Class 1 and Class 2, likely due to higher incomes (cf. above).

Price elasticities of demand were estimated based on Model 1. A 1% increase in price on average led to 1.51% decrease in choice probability, revealing that the direct price elasticity of demand for rhino horn was elastic. Despite price sensitivity being affected by income, the absolute effect on the elasticity measure is small as price elasticity only varied very little across the income distribution. It also only varied little between different levels of peer experience (Table 3).

Marginal willingness to pay for 100 g of rhino horn was also calculated based on the RPL model. Without the effect of peer reference, respondents were on average willing to pay an additional VND 45.5 million and VND 30.3 million for wild- and semi-wild horns, respectively, compared to farmed horns. However, they were, on average, also willing to pay a premium of VND 46.3 million for horns from legal sources. To incorporate the influence of peer reference, we calculated the marginal WTP for each attribute level at different levels of the peers attribute using the estimated parameters from Model 2 (Fig. 1). As expected, the marginal WTPs decreased when the level of peers experiencing no effect increased ($p < 0.01$).

4. Discussion

Despite various studies and investigations of the rhino horn trade and rhino horn consumption (e.g., Cheung et al., 2021a, 2021b, 2021c, 2018; Van Roon, 2019; USAID Vietnam, 2018; USAID Wildlife Asia, 2018; Crosta et al., 2017; Hanley et al., 2017; Stoner et al., 2017; Hübschle, 2016; Milliken and Shaw, 2012), critical information that would help guide trade policy decisions is still missing. Notably, few previous studies have involved a larger sample of own-reported rhino horn consumers and intended consumers. Understanding consumer preferences, trade-offs, and demand elasticities can provide crucial insights for the informed design of policy interventions and behaviour modification campaigns and for predicting the outcome of a legalised trade (Dang and Nielsen, 2021a; Hinsley and 't Sas-Rolfes, 2020). Biggs et al. (2013) suggested that "A highly regulated legal trade based on the renewable cropping of horns from rhinos is likely to succeed if these

conditions are met" (pp. 1038–1039). The conditions include that: (i) regulators can prevent a threatening level of laundering of illegal supply; (ii) legal suppliers can deliver the product more efficiently, reliably, and cost-effectively than the illegal market; (iii) demand does not escalate to dangerous levels as the stigma associated with the illegality of the product is removed; and (iv) legally harvested horn from live animals can substitute for horns obtained from wild poached animals (Biggs et al., 2013, p. 1038). Below, we discuss our results with reference to these conditions and the literature. We do not aim to conduct a detailed economic analysis of the rhino horn trade debate, but our empirical evidence has important implications for the consideration of a legal trade.

Condition one: Laundering wild animals has occurred in the legal trade of various species (Knights et al., 2015; Lyons and Natusch, 2011; Brooks et al., 2010; Nijman and Shephard, 2009). Our results indicate that consumers generally prefer and are willing to pay more for legal horns. This will provide suppliers of poached rhino horn motivations for arbitrage, i.e., laundering of illegal horns into the legal market to increase profits (Fischer, 2004). Preventing laundering is complicated in the context of widespread corruption in nations along the rhino horn trade route (Crosta et al., 2017; Hübschle, 2016; Janssens and Trouwborst, 2018; Stoner et al., 2017). Illegal suppliers could use fake documents to cheat less knowledgeable or law-abiding consumers. And authorised suppliers could use the legal trade as a cover to hide illegal stocks offered to law-ignoring consumers at lower prices. These laundering tricks have been found in other markets, including Hong Kong's ivory market (Knights et al., 2015). Although it is probably impossible to entirely prevent, governments can discourage laundering through various regulatory initiatives such as certification and permit systems, rhino DNA index system (RhODIS), and microchipping (Chen and 't Sas-Rolfes, 2021; Rubino et al., 2018; Harper, 2013; Conrad, 2012). These initiatives can help discriminate between legal and illegal horns, which is useful mainly in prosecution and conviction (e.g., see Harper, 2013). Yet, their contribution to reducing laundering relies on the ability of law enforcement officers to check all rhino horns in the market, including those in private ownership, which is limited. Hence, the extent to which a legal trade will lead to reduced poaching through condition one depends on the quality of regulatory mechanisms as well as the cost of supplying legal relative to illegal horns.

Condition two: Due to avoided risk of confiscation and the consequent ability to transport larger quantities of rhino horn through official channels from Africa to Asia, the supply of legal horns can be more reliable, efficient, and cost-effective than trafficking. However, whether a legal trade can contribute to discouraging poaching depends on the displacement effect created by legal suppliers. The supply of certified legal horns should be large enough "such that residual demand is very low – that is, below the threshold for poaching" (Fischer, 2004, p. 937). Taylor et al. (2017), in this respect, estimated that the supply of legal rhino horns from South Africa from naturally dead rhinos, dehorning, trophy hunting, and government and private owner stockpiles could range from 5319 to 13,356 kg annually. If we use the annual number of rhinos poached in Africa as an indicator of the illegal supply, it has never exceeded 1500 individuals (UNODC, 2020). With an average horn weight of five kilograms per white rhino (Vigne and Martin, 2016), the total volume of illegal supply has never exceeded 7500 kg annually. As a small piece of rhino horn (e.g., 100 g) can be used for a long time, even years, depending on the frequency of use, the marginal effect of supplying legal horns to Vietnam is likely large enough to discourage poaching – depending on the price difference between these goods. To this point, our results showed that the marginal WTP for 100 g of legal horn (VND 46.3 million) is higher than that for wild (VND 45.5 million) and semi-wild horns (VND 30.3 million).

Condition three: The extent to which demand will increase is an open question in the debate about trade legalisation. In this case, demand must be understood as the quantity of rhino horn that consumers are willing and able to purchase over a price range in a given time period.

Table 3
Direct price elasticity of demand for rhino horn.

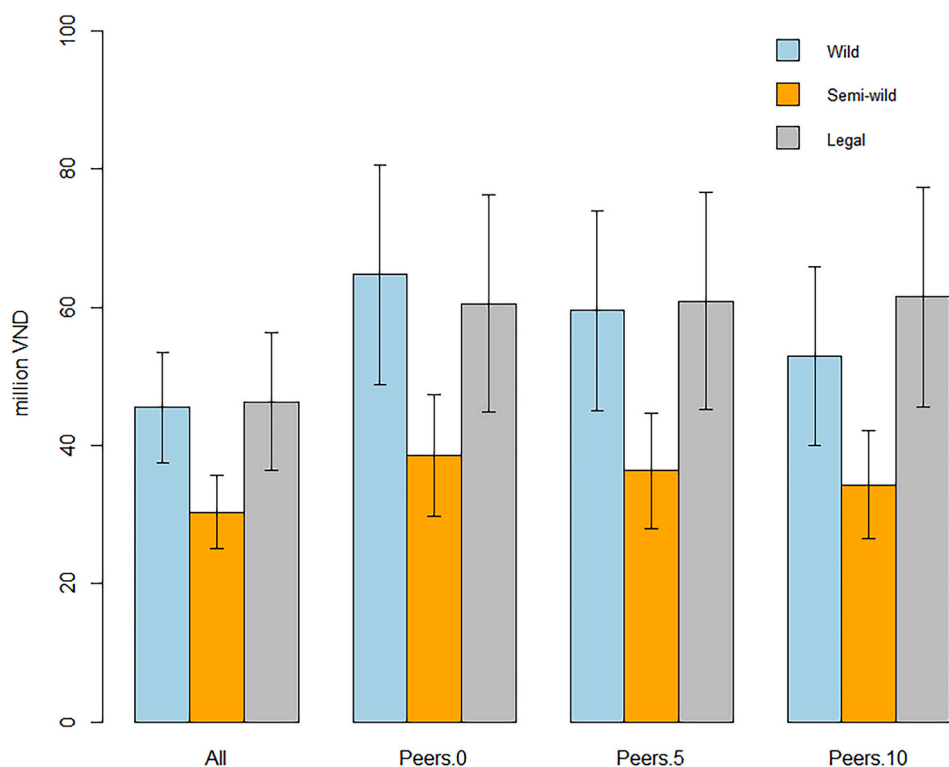|	Peer reference			Income		
	Peers = 0	Peers = 5	Peers = 10	1st quartile	2nd quartile	3rd quartile
Elasticity	1.505	1.507	1.523	1.511	1.512	1.512

Fig. 1. Marginal WTP of attributes presented to respondents (in million VND). I.e. the additional amount that consumers are willing to pay for an upgrade from farmed rhino horn to semi-wild and wild rhino horn and from illegal to legal rhino horn. The three bars to the left (All) represent WTP for wild, semi-wild, and legal, calculated using the estimated parameters from Model 1 (no interactions with peers). The nine bars to the right (Peers.0, Peers.5, Peers.10) represent WTP for wild, semi-wild, and legal at different levels of peers experiencing no or a negative effect of using rhino horn (0, 5, 10), calculated using the estimated parameters from Model 2 (including interactions with peers). Lines with whiskers are standard errors.

The potential aggregate demand is unknown. Assessing it requires a large-scale survey in major consumer markets, incl. China and Vietnam, as well as in potentially reawakening old markets such as Japan, South Korea, and Yemen (Milliken and Shaw, 2012) and emerging new markets such as Lao PDR (Vigne, 2013). In the third condition, Biggs et al. (2013) only mentioned the effect of stigma on demand. We find this condition incomplete. A demand escalating to "dangerous levels" as described by Biggs et al. is taken to mean that the aggregate demand exceeds the legal supply to the extent that poaching to supply the residual demand will increase to a level driving population decline. However, there are a number of factors in addition to legality that may modify demand, including most notably price and rarity of the product (Hall et al., 2008), availability and price of substitute products (Chen and 't Sas-Rolfes, 2021) and consumer preferences about quality and attention to animal welfare (Wyatt et al., 2021; Hanley et al., 2017), as well as consumer income, use and perceived need for rhino horn (Dang and Nielsen, 2018; Hinsley and 't Sas-Rolfes, 2020). Building an economic model of trade in endangered species products, Fischer (2004) argued that two demand externalities – stigma and outrage – impact the utility of using such products. The stigma effect arises from the illegal and inhumane nature of the trade, for instance in rhino horn (Fischer, 2004). Outrage, on the other hand, depends on the absolute size of the illegal activity and originates in altruism or existence values (Fischer, 2004). Stigma will likely be reduced by a legal trade (whereas outrage will not), potentially leading to increased demand in terms of the quantity of rhino horn among law-abiding consumers (Fischer, 2004). We found that consumers generally prefer to buy rhino horn, as opposed to the do-not-buy option, in both the legal trade and trade bans scenarios suggesting a very limited stigma effect. This resonates with previous studies finding that the use of rhino horn as traditional medicine attracts no or very little stigma among traditional medicine practitioners and consumers (Cheung et al., 2020; Hanley et al., 2017; Truong et al., 2015). Particularly, in-depth interviews with 30 rhino horn consumers revealed that the plight of rhino populations, Vietnam's penal code, and the possible contribution to international crime did not influence their use of this product (Dang and Nielsen, 2018). Hence, the observed

preference for legal horns in this study may simply derive from the avoided risk of sanctions and buying fake products. In that case, any effect of stigma (as well as outrage) of a legal trade is unlikely to have major effects on demand. However, an associated increased availability and knowledge about how to acquire rhino horn may lead to increased demand (Dang and Nielsen, 2021b). Evaluating to what extent the demand curve is likely to shift due to a possible increase in the quantity demanded requires assessing a spectrum of factors besides the stigma effect (cf. above), as well as complex interactions between legal and illegal markets (Fischer, 2004), which is beyond the scope of this study.

Condition four: Whether legally harvested horn from live rhinos is an adequate substitute for horns from poached wild rhinos depends on consumer preferences for the source and legality of the horn, influenced by their knowledge about rhino farming. Our results revealed consumer preference for wilder sources of rhino horn, corroborating the results of previous studies that wild horns are believed more potent than farmed (as defined above) horns (Dang and Nielsen, 2018; Hanley et al., 2017). This suggests that farmed horn (as hypothetically described in this study) is not a perfect substitute for wild products in a legal trade. Hence, the chances of a legal trade in dehorned rhino horn to succeed may increase by simultaneously informing consumers about rhino farming practices (cf above, Table 1).

We also found large heterogeneity in consumer preferences. Higher-income consumers (i.e., Class 3 members) are less concerned about legality. Hence, in case the legal supply of wild horns is not sufficient, and maybe even if it is, these consumers will likely purchase from illegal sources thus continuing to incentivize poaching. Choosing between wild and semi-wild horns, a larger proportion of respondents, including those in lower-income brackets and with less urgency of using rhino horn (i.e., members of Class 1 and Class 2 in the LC model), preferred semi-wild over wild horns. Overall, our results suggest that the legal horn supply should be at least semi-wild in the continuum of management practices and supply large enough to create a significant displacement effect to reduce poaching (cf. above). Chen and 't Sas-Rolfes (2021) suggest that supplying synthetic rhino horns, assumed indistinguishable from natural products, can also benefit rhino conservation. However, their assertion

depends in part on the almost thirty-year-old assumption that rhino horn demand is price inelastic (Milner-Gulland, 1993), contradicted by our findings. More importantly, the medicinal efficacy of synthetic products is likely to be considered nil (see Cheung et al., 2021a), and consumer preferences and their ability to distinguish between artificial and natural products have not been examined. Hence, this initiative may only serve the market segment where consumers use synthetic products for display (see Gao et al., 2016).

Our analysis indicates that the four conditions suggested by Biggs et al. (2013) are likely to be met only to some degree but that a legal trade has the potential to lead to incremental reductions in poaching. However, even fully meeting these conditions is no guarantee for the success of a legal trade. Black markets will likely continue to exist in parallel to any legal trade. Notably, all these conditions disregard other factors influencing demand (cf. above). We found a negative effect of price on preferences for purchasing rhino horn. I.e., consumers were sensitive to price, meaning that if the price is reduced (e.g., through market regulations) to the extent that it becomes more affordable and potentially also to consumers in lower-income brackets, then demand is likely to increase considerably (Eikelboom et al., 2020). Given the possibility of laundering (cf. above), Fischer (2004) suggested that to minimize poaching, legal sales should be kept at a level that minimizes prices and maximize the consumption of legal products by law-ignoring consumers. However, if the legal price was too low, legal sales would unlikely cover management and production costs (Collins et al., 2016), while the quantity demanded would increase by a higher proportion as demand is price-elastic. If the legal price was higher than black market prices, a legal trade could increase poaching through motivations for arbitrage (Fischer, 2004). Therefore, the pricing strategy of legal suppliers should be based on both black market prices and the break-even point for rhino farmers, considering management and transaction costs. A legal trade should bring profits to private rhino owners to incentivize contributing to rhino conservation. Rubino et al. (2018) suggest that rhino horn must be sold at a minimum price of US$11,500 per kg to incentivize private rhino owners. This price is well below any black market prices ever reported (ranging from US$17,852 to US$65,000 per kg) (Van Roon, 2019; Stoner et al., 2017; 't Sas-Rolfes, 2012), which enables a flexible pricing strategy should a legal trade be introduced. Our results revealed that our respondents' marginal WTP for legal horns is approximately US$20,000 per kg. If the starting price of a centrally regulated trade for legal supply was set at a similar rate, this surplus might contribute to cover the management costs of the regulatory authority. Setting a lower price would allow attempts to outcompete illegal suppliers (assuming that laundering could be controlled) but would entail the risk of increasing demand. Of course, illegal suppliers can lower prices too in order to compete, and poachers are likely to be insensitive to price changes and may continue to poach rhinos despite falling prices (Crookes, 2017). Exactly how these markets will interact and what the likely outcome of a potential price war is remain unclear. Hence, the Private Rhino Owners Association suggested that the best way to examine market interactions is to pilot test a legal trade (PROA, 2021).

Furthermore, our results provide insights for the design of behaviour modification strategies. Motivations for using rhino horn can be affected by different reference groups, including informational, utilitarian, and value-expressive referents (Dang et al., 2020). We found that the number of peers having used rhino horn with no or a negative effect increased price sensitivity and reduced preferences for more expensive wild-sourced horn. This resonates with the results of our focus group discussions and the findings of Dang et al. (2020) that their respondents mostly listen to peer users (e.g., family members, friends, colleagues who have used rhino horn) in their decision to purchase or use rhino horn. Peer reference had a small effect on WTP for semi-wild and legal horn but a relatively large effect on WTP for wild-sourced horn. As the number of peers having used rhino horn with no or a negative effect increased from 0 to 10 (out of 10, i.e., 100%), WTP for wild horn

declined by more than 18% (see Fig. 1). Hence, campaigns publicising consumers negative or no experienced effect of rhino horn for health treatment may contribute to reducing demand and hence increase the ability of a legal trade to meet demand, thereby contributing to rhino conservation.

Our findings include results contradicting previous primarily theoretical studies (Crookes and Blignaut, 2015; Crookes, 2017; Milner-Gulland, 1993; Vigne et al., 2011) and empirical studies based on consumers of a different profile (Hanley et al., 2017; USAID Vietnam, 2018). While rhino horn has long been considered a luxury good with inelastic demand (Crookes and Blignaut, 2015; Brown and Layton, 2001; Milner-Gulland, 1993), we found that the preference in all income groups is elastic to price changes. Variation in elasticities between different levels of peers and the urgency of using rhino horn was, however, small. Hanley et al. (2017), using a choice experiment, found that a legally controlled trade would reduce consumer WTP for rhino horn. In contrast, we found that consumers are willing to pay more for horns from legal sources. This contradiction could derive from differences in the study design and, more importantly, the sample composition. Hanley et al.'s sample was composed of younger individuals with lower income - which does not align well with the characteristics of typical rhino horn consumers (Truong et al., 2015). Our sample in comparison consisted of own-reported consumers and intenders mainly composed of middle-aged and elderly males from higher-income brackets consistent with the typical profile of rhino horn consumers in Vietnam (Truong et al., 2015). A large proportion of our sample of own-reported consumers (64% of the total sample) stated not having bought the rhino horn themselves, implying instead having been offered to drink rhino horn powder or received a piece of horn as a gift. If so, one would expect them to not be price sensitive. However, there was no difference in price sensitivity between consumers and intenders (examined through an interaction between price and a dummy representing consumers vs intenders - Appendix F, Supplementary materials), indicating that individuals only consuming and those purchasing rhino horn are likely not different in their preferences. This may be due to the reciprocity expected when offered a drink of rhino horn powder or being gifted a piece of rhino horn, meaning that these consumers likely are considering purchasing rhino horn to return the favour and increase their own prestige.

5. Conclusions

Our study provides important insights into consumer preferences and demand elasticities for rhino horn. Albeit insufficient to unequivocally confirm the consequences of a legal trade, our results show some support for the argument that a legal trade could shift the preference of a large proportion of consumers to legally supplied horns. Consumers generally prefer and are willing to pay more for wilder horns, especially those with a confirmed legal origin. However, we found considerable heterogeneity in consumer preferences. Higher-income consumers have a stronger preference for wild horns and are less sensitive to legality, although the size of the effect is minor. We also found that the preference of all income groups is price elastic, suggesting that the small piece of rhino horn customarily used as a gift and grind into a powder dissolved in water for drinking is a normal good. The extent to which a legally controlled trade can contribute to reducing poaching depends on the capacity to supply sustainably harvested wild and semi-wild horns to the market at competitive prices, changing consumer preferences towards legal products, and law enforcement efforts along the value chain. Although the illegal market will likely continue to exist, the profits from selling legal horns can be used by rhino custodians to strengthen on-site anti-poaching activities. Important questions remain unanswered, including to what extent legal supplies can meet potentially rising market demand and whether consumers can be convinced that less wild rhino horn has similar health benefits, if any, as those of wild rhino horn. Furthermore, our study only generates insights into Vietnamese

consumers, while Chinese tourists visiting Hanoi to purchase rhino horn and the mainland Chinese market remain mostly unstudied. While more evidence is needed to confirm whether a legal trade will contribute to rhino conservation or not, demand reduction campaigns should continue. Our results suggest that basing campaigns on the influence of peer reference could be a viable strategy to reduce demand by encouraging people who have experienced no or negative effects of using rhino horn to step forward in the debate.

Authors' contributions

All authors contributed to the conceptualization of the project and the development of the survey and sampling procedures. D.V.H.N., M.R. N. and J.B.J. jointly designed the study. D.V.H.N. led the fieldwork, analysed the collected data, and wrote the first draft of the manuscript. All authors reviewed and edited the manuscript and gave final approval for publication.

Data availability

The dataset analysed in this study is available at the University of Copenhagen's Electronic Research Data Archive (ERDA) at doi:10.1 7894/ucph.89589f25-64ed-47c9-a5db-f7cc4252efd2 (Dang Vu, 2021).

Code availability

The R and NGENE script used in this analysis is available from the authors upon reasonable request.

Declaration of Competing Interest

The authors declare no competing interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolecon.2021.107287.

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