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The impact of a legal trade in farmed tigers on consumer preferences for tiger bone glue – Evidence from a choice experiment in Vietnam

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ABSTRACT

Demand for tiger parts and products has fuelled the poaching of wild tigers. As the supply of wild tigers has become scarce, tiger farming has emerged as an alternative source and proliferated in several Asian countries with unclear implications of a legalized trade in farmed tigers on wild tiger demand. We conducted a choice experiment with 228 Vietnamese tiger bone glue consumers investigating their preferences and trade-offs for different attributes of their purchase choice, including legality, source, purity, and price. We calculated consumers' willingness to pay for each attribute level under the current trade ban and in a hypothetical legal trade. Consumers preferred and were willing to pay more for wild than farmed tiger glue and a higher proportion of tiger bone in the glue. Consumers also preferred legal over illegal sufficiently for most to switch from illegal wild to legal farmed tiger. Hence, a legal trade will shift preferences significantly towards farmed tiger glue from legal sources but will not eradicate demand for wild tigers, likely leading to the parallel operation of legal and illegal markets. We discuss the implications of the results for conserving wild tigers through efforts to manage demand in Vietnam.

1. Introduction

There are currently more tigers living in captivity than in the wild. A large proportion of tigers in captivity are bred and raised to supply the demand for tiger parts, including tiger bone glue in Asian markets (EIA [Environmental Investigation Agency], 2017; Ammann, 2015). International trade in all five tiger subspecies has been banned since 1987 (Abbott and Van Kooten, 2011). Yet, the global tiger population declined by about 50% from the 1990s to 2014 due to multiple factors (Goodrich et al., 2015). It is clear that the trade ban has failed to prevent tigers from being poached (Rasphone et al., 2019; Graham-Rowe, 2011), and the illegal tiger trade shows no sign of abating (McCoy, 2019; Indenbaum, 2018; Goodrich et al., 2015). Poaching for illegal trade is the primary threat to wild tiger populations, while habitat loss, degradation and fragmentation are considered the driving force that facilitates poaching (EIA [Environmental Investigation Agency], 2017; Goodrich et al., 2015; Dinerstein et al., 2007; Lapointe et al., 2007; Nowell and Xu, 2007). Domestic trade in tiger bones and medicine from tiger bone was banned in China in 1993 (Dinerstein et al., 2007) and in Vietnam in 1994 (CITES, 2008). However, demand for tiger parts and products is likely increasing, probably due to the rising wealth of consumers in these markets while tiger farms have proliferated across Southeast Asia and China (Davis et al., 2020; EIA [Environmental Investigation Agency], 2017; Stoner et al., 2016). Consequently, studies combining insights about remaining tiger populations and their habitat, poaching and demand from international markets estimate that tigers will likely become extinct in the wild in the near future (see Abbott and Van Kooten, 2011).

China and Vietnam are considered major consumer markets for tiger parts and products (Coals et al., 2020; Davis et al., 2020; Goodrich et al., 2015; Wong, 2015; Nowell, 2010), with uses including traditional medicine, curios, decoration, wild meat, and public and private display (Broad and Damania, 2010). All parts and products of a tiger have a market value (Krishnasamy and Stoner, 2016), but tiger bone is the most popular product (Coals et al., 2020; Davis et al., 2020). Tiger bone has been used for centuries in traditional medicine in many Asian countries such as China, Japan, South Korea, and Vietnam, with perceived benefits for treating arthritis, rheumatism, and other ailments of the muscles and

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bones (Dinerstein et al., 2007; Mills and Jackson, 1994). Tiger bone is also believed to have anti-inflammatory and pain-killing effects (Lapointe et al., 2007). Traditionally, tiger bone was dried and ground into a powder, and mixed with other ingredients in concoctions prescribed by traditional medicine practitioners (Broad and Damania, 2010). In Vietnam, tiger bone is often cooked into a glue known as *cao hổ* (in Vietnamese) that can be eaten directly or put into a medicinal wine (Krishnasamy and Stoner, 2016). This process involves two to three days of cooking in high-pressure cookers until tiger bones are completely dissolved to a glue-like substance (K. Ammann, personal communication, June 25th, 2021). The use of tiger bone glue (henceforth tiger glue) can be treated as a distinct trade segment in its own right (Broad and Damania, 2010). Its current black market price ranges from US$6500 to US$13,000 per kilogram in Vietnam, depending on the proportion of tiger bone in the glue (Tiger trader, per. comm., March 28th 2020).

Tiger farming is proliferating across several countries, attracting attention from academics and international media (Davis et al., 2020; McCoy, 2019; Bale, 2018; Liu et al., 2015). The EIA (2017) identified more than 200 captive tiger farms in Asia, with China, Lao PDR, Thailand, and Vietnamese facilities housing between 7000 and 8000 individual tigers - more than double the number of tigers left in the wild. Many of these farms operate legally by being issued with a zoo license but hide illegal breeding, killing, and selling of tigers in locked away areas (K. Ammann, personal communication, June 25, 2021). Although tigers may not be bred solely to supply the illegal trade in their parts and derivatives, it is estimated that 54% of tiger seizures in these four countries have a captive-bred origin (EIA [Environmental Investigation Agency], 2017). The Chinese government has considered partially removing the domestic tiger trade ban to allow products from farmed tigers to supply to the traditional medicine market (Coals et al., 2020). But the potential effect of tiger farming on poaching of wild tigers remains highly controversial (Abbott and Van Kooten, 2011; Kirkpatrick and Emerton, 2010; Gratwicke et al., 2008; Dinerstein et al., 2007; Jiang et al., 2007; Lapointe et al., 2007; Mitra, 2006).

Proponents of tiger farming argue that products from farmed tigers would satisfy consumer demand and reduce the economic incentives for poaching (Abbott and Van Kooten, 2011; Jiang et al., 2007; Lapointe et al., 2007; Mitra, 2006). Opponents, on the other hand, argue that lifting or weakening the trade ban would remove the stigma on using tiger products and increase demand, which in turn will increase poaching (Kirkpatrick and Emerton, 2010; Gratwicke et al., 2008; Dinerstein et al., 2007). However, economic analyses of wildlife farming, including tigers, is constrained by a lack of reliable data on consumer preferences and trade-offs, and particularly about the price elasticity of demand. This lack of information constrains options for informed decisions and policies about tiger farming and behaviour modification campaigns to reduce threats to wild tiger populations.

Here we aim to assess the likely effects of implementing a legally controlled trade in farmed tigers on consumer demand for tiger glue usage in traditional medicine in Vietnam and its consequences for wild tiger populations. We interviewed individuals who had recently consumed or intend to consume tiger glue and conducted a choice experiment to assess their preferences for different attributes of this good, including the source of the tiger, purity (i.e., proportion of tiger bone in the glue), and price. We calculated consumers' Willingness to Pay (WTP) for each attribute level and tested the effect of a legal trade and socio-demographic covariates by including interaction terms in the model to further explore what changes will most effectively influence demand for tiger glue. We discuss our results in relation to five criteria identified by Tensen (2016) that must be met so that wildlife farming will benefit species conservation.

2. Methods

2.1. Study areas

We conducted interviews in Hanoi, Vietnam's capital and second-largest city by population (General Statistics Office of Vietnam, 2019). As of 2019, Hanoi is home to more than 8 million inhabitants with an estimated average GDP per capita of VND 6.34 million per month (approx. US$270) (General Statistics Office of Vietnam, 2019). The consumption of luxury wildlife products (e.g., rhino horn) as traditional medicines and status symbols is popular among the affluent class in Hanoi (Dang and Nielsen, 2021; Dang Vu and Nielsen, 2021; Dang Vu and Nielsen, 2018; Cao Ngoc and Wyatt, 2013; Drury, 2011). Hanoi is also considered a major market for tiger parts and products, especially tiger glue (Coals et al., 2020; Davis et al., 2020).

2.2. Choice experiment and questionnaire design

We focused on the use of tiger glue as a traditional medicine in the treatment of diseases. We followed a mixed-methods approach to design the choice experiment. First, we reviewed the relevant literature and interviewed representatives from Vietnam's CITES Management Authority, conservation NGOs, undercover investigators, researchers, and experts working with the tiger glue market to develop an initial list of attributes of the consumer choice to purchase tiger glue. We then conducted focus groups to discuss this list with tiger glue consumers, traditional medicine practitioners, and individuals with a history of trade in tiger parts and products. Three focus groups with 3–4 participants each (11 in total) were conducted between December 2019 and March 2020. According to the focus groups, there were two options for consumers to purchase tiger glue. Consumers can either form a group to share the cost of buying a whole tiger (its carcass or skeleton) and other ingredients (e.g., medicinal plants, turtle shell, deer antler velvet, saiga antelope bone) required to make the glue and then hire an expert to produce the tiger glue. This was considered the most reliable way to ensure the product quality but incurred higher initial investments and the risk of being caught by the police. Alternatively, a consumer can purchase one or a few hundred grams of tiger glue from producers or retailers. We focus here on the second option, which is more common and incurs a low risk of legal sanctions because no tiger DNA can be found in tiger glue (K. Ammann, personal communication, June 25th, 2021). The final list of attributes in the choice experiment design includes: source of the tiger (wild or farmed tiger), purity (i.e., the proportion of tiger bone in the glue: low = 30%, medium = 50%, or high = 70%), and the price per 100 g of tiger glue in million Vietnamese Dong (VND) (15, 20, 25, 30, 35, or 40). At the time of the survey, one million VND was equivalent to 44 US dollar.

Combining the attributes and their levels produced 36 alternatives. We used the NGENE software to make an initial orthogonal design consisting of 36 choice sets. The choice sets were transformed into choice cards. Each choice card comprised two alternatives: "Tiger glue 1," "Tiger glue 2," and a "Do not buy" option (see Appendix A, supplementary materials for an example of a choice card). We pilot tested the design on a sample of 20 respondents and estimated a multinomial logit model (MNL) based on the data collected from the pilot. We used the priors from this model to make the final design, a d-efficient design including 12 choice sets, which we then distributed into two blocks. Hence, each block was comprised of six choice sets. Each respondent received both blocks, but the block design was chosen to allow for the possibility that the interviewer had to shorten the interview if respondents experienced fatigue. However, that option was not used, and all respondents evaluated all 12 choice sets. To reduce the cognitive burden on respondents, we added illustrative pictures of wild and farmed tigers to the choice cards to depict the 'source' attribute and differentiate between its two levels.

The sample was equally divided into two treatments to assess the

impact of a legally controlled trade in farmed tigers. Every second respondent answered their choices in the context of a hypothetical legal trade, whereas the other half of the sample made choices in the current context, i.e., illegal trade. The questionnaire included an introduction script describing the study objectives, an informed consent form, structured questions about respondents' behaviours, beliefs, and knowledge, and finally, the choice experiment. The choice experiment was proceeded by a description of the attributes and their levels and the hypothetical scenario of a legal trade in farmed tigers (only presented to half of the respondents) to ensure that respondents received identical information from enumerators (see Appendix B, supplementary materials). We integrated a cheap talk script into the introduction to minimize hypothetical bias (Tonsor and Shupp, 2011). Furthermore, we reminded respondents of the associated cost, benefits, and risks of their choices, as well as their budget constraints. We used follow-up questions to identify free-riders and irrational respondents, i.e., those not striving to maximize utility (see Appendix E, supplementary material). We then asked respondents to rate the importance of each attribute of their choices on a four-point Likert scale (1 = not important, 4 = extremely important). Finally, the questionnaire ended with questions about the respondents' socio-demographic characteristics and whether anyone in their families urgently needed tiger glue for health-related purposes (following Dang et al., 2021).

2.3. Data collection

We approached participants in previous studies on rhino horn who had also admitted using tiger glue (henceforth consumers) or intending to use this product in the future (henceforth intenders) (Dang and Nielsen, 2021; Dang et al., 2021; Dang Vu et al., 2020). We then expanded this sample using snowballing and the personal networks of the first author and three enumerators to 228 respondents. Data was collected through face-to-face interviews from May to August 2020. A typical interview lasted 20 min and was conducted in a location convenient to the respondents.

2.4. Data analysis

Choice experiments are based on random utility theory (McFadden, 1974), which holds that consumers tend to maximize their utility when choosing between alternatives (e.g., products or services) and that utility can be observed with an error. Utility is determined by the levels of the attributes in the chosen alternative plus a random and unobservable component. Different models can be used to analyze choice experiment data (Mariel et al., 2021). In this study, we estimated both random parameter logit (RPL) and latent class (LC) models. The RPL model has the advantage of computational flexibility and can accommodate heterogeneity in the respondents' preferences. It also relaxes the assumption of the Independence of Irrelevant Alternatives (IIA) inherent in the multinomial logit (MNL) model, which is often violated (Train, 2009). We used 1,000 Halton draws when estimating the RPL model. The LC model accommodates unobserved preference heterogeneity across individuals by putting them into latent classes. In each class, preferences are assumed identical (Hess, 2014). In the current paper, we use a version of the LC model, where only selected attributes differs between classes, i.e., a discrete mixture model. This model was selected to investigate heterogeneity in the preference for legality in particular.

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 (Train, 2009):

$$P_{ni} = \int [(\exp(\beta_n' X_{ni}) / \sum_j \exp(\beta_n' X_{nj})] f(\beta) d\beta \quad (1)$$

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 function of the distribution of β with an assumed distribution.

We assumed that all attributes were normally distributed, except price. To avoid theoretical inconsistencies of positive preferences for price, we set the distribution of price to log-normal. We added an Alternative Specific Constant (ASC), which takes the value of one for the "Do not buy" option and zero otherwise, to the model to capture preferences for not buying regardless of the attribute levels in other alternatives. We specified the utility function in our analysis as follows:

$$U = \beta_{ASC} * ASC + \beta_{wild} * wild + \beta_{prop\_50} * prop\_50 + \beta_{prop\_70} * prop\_70 + \beta_{price} * price + \varepsilon \quad (2)$$

We followed Hess and Palma (2019) and estimated the direct price elasticity of demand for tiger glue. This is defined as the percentage change in the probability of choosing a particular alternative in the choice set given a 1% change in the price of that alternative (Train, 2009). We followed Mariel et al. (2021) to estimate the marginal Willingness To Pay (WTP) using the following equation:

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

which is the price that consumers are willing to pay for 100 g of tiger glue 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 included socio-demographic variables and other covariates one at a time through interaction with the attribute levels to examine their influence on consumers' choices. We used the Apollo package (Hess and Palma, 2019) to conduct the analysis in RStudio version 1.2.5042.

This study was ethically approved by 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). We complied with all policies and procedures of the authorizing Ethical Review Boards and followed a strict policy of informed consent given the sensitive nature of the tiger glue market. We informed potential respondents of the study purposes, potential benefits and risks of their participation in the study, and that they could withdraw from the interview whenever they want to. Interviews were conducted by a team of enumerators fully trained to follow the ethical guidelines. We used password-protected tablets to collect data from interviews, which were uploaded to an encrypted cloud in real-time. The University of Copenhagen's IT department handled all security issues related to the data collection and storage to avoid theft or loss of hardcopy questionnaires, which could enable others to obtain incriminating and personal data. Only the study team had access to the collected data in the cloud server.

3. Results

The survey was administered to a sample of 228 respondents, including 182 consumers and 46 intenders (cf. above). Respondents were aged between 23 and 81, with a mean age of 49 and median 46. The majority of respondents were males (84%), married (97%), and university graduates (73%) or had a higher education (14%). Tiger glue consumers were more likely to be males ($t = 3.53$; $p < 0.01$) and have higher education levels ($F = 2.58$; $p < 0.05$) than intenders. About one third (27.6%) of the respondents were government officials, while nearly half (43%) were business owners or self-employed (Appendix C, supplementary materials). The average monthly individual income of the respondents was in the range of VND 40–49 million (approx. US$ 1740–2130), which was more than 10 times higher than the national average of VND 3.76 million (approx. US$ 163) in 2018 (General Statistics Office of Vietnam, 2019). The most prevalent stated uses of tiger glue were for treating bone-related diseases (40%) and for general health benefits (32%). Some respondents also used tiger glue to prevent diseases (5%) and enhancing

sexual prowess (6%). Nearly half of the respondents (46%) admitted that they or their family members had purchased tiger glue, while the other half (48%) claimed having received it as a gift, including being shared at parties (Appendix D, supplementary materials). Notably, 44.3% of the respondents believed that using 100 g of tiger glue will not incur legal sanctions. A large proportion of the respondents also consumed other traditional medicine and exotic food from animals such as rhino horn (43%), bear bile (89%), gayal bile (37%), deer antler (45%), pangolin meat and scales (25.4%), and shark fin (50%).

Consumer preferences. We recorded a total of 2,736 choices by the respondents, of which the "Do not buy" option accounted for 21.3%. We present two RPL models and one LC model for the choice experiment in Table 1. For the RPL model we do not distinguish between the two splits of whether respondents received the question in a legal or illegal setting, but we do in the LC model. Model 1 only contained attributes on the choice cards. Model 2 included interactions with usedtg, providing the best fit (AIC = 2908.40) of the tested options. We also added interactions with socio-demographic variables (incl. age, gender, marital status, education, occupation, income) to the RPL models but found no significant effects on preferences. The ASC coefficient was negative and significant, suggesting that respondents preferred to buy tiger glue over the "Do not buy" option. Respondents preferred wild over farmed tiger glue.

Table 1
Estimation results for RPL and LC models (Standard errors of the estimates are provided in parentheses).

	RPL		LC	
	No interactions	Interact with usedtg	Class 1	Class 2
ASC	−1.623***	−1.088***	−2.025*** (0.148)	
	(0.433)	(0.409)		
Wild	1.814***	0.922**	0.863***	3.726***
	(0.382)	(0.516)	(0.070)	(0.440)
Prop_50	4.817***	3.520***	0.366*** (0.063)	
	(0.290)	(0.424)		
Prop_70	7.466***	5.475***	0.498*** (0.112)	
	(0.441)	(0.563)		
Price	−1.723***	−1.785***	−0.068*** (0.005)	
	(0.075)	(0.147)		
Wild × legality			−5.562***	−2.790***
			(0.546)	(0.447)
Wild × usedtg		0.985*		
		(0.733)		
Prop_50 × usedtg		2.076***		
		(0.522)		
Prop_70 × usedtg		3.035***		
		(0.707)		
Price × usedtg		−0.028		
		(0.025)		
Sd.ASC	−5.734***	−5.919***		
	(0.515)	(0.610)		
Sd.wild	−8.686***	−9.726***		
	(0.670)	(0.826)		
Sd.prop_50	−1.292***	−1.496***		
	(0.249)	(0.259)		
Sd.prop_70	2.318***	2.715***		
	(0.251)	(0.292)		
Sd.price	0.393***	0.451***		
	(0.035)	(0.053)		
Pr(class)			0.69	0.31
No. of choice sets/ respondents	2,736/228	2,736/228	2,736/228	
Pseudo R^2	0.52	0.52	0.25	
LogLik	−1,450.47	−1,449.20	−3,660.87	−3,567.61
AIC	2,920.94	2,908.40	4,534.71	
BIC	2,980.08	2,991.20	4,587.94	

Notes: 1. ***, **, * indicate significance at 1%, 5%, 10% level.
2. The dummy legality takes the value of 1 if the trade in farmed tigers is legal and 0 otherwise.
3. The dummy usedtg takes the value of 1 if the respondent reported having used tiger glue and 0 otherwise.

Table 2
WTP of consumers and intenders for 100 g of each product type.

Product type	WTP (in million VND)	
	Consumer	Intender
Farmed, 50% of tiger bone	35.4 (11.7)	19.0 (6.3)
Farmed, 70% of tiger bone	53.8 (16.5)	29.5 (9.1)
Wild, 50% of tiger bone	47.4 (17.3)	24.0 (8.6)
Wild, 70% of tiger bone	65.8 (22.1)	34.5 (11.4)

Notes:
1. Standard errors of the estimates are provided in parentheses.
2. Farmed and 30% are set as reference levels.

Respondents also preferred a higher proportion of tiger bone in the glue while price as expected had a negative effect on the choice to purchase. Consumers were more likely to choose to buy tiger glue than intenders. Having previously used tiger glue (usedtg) also increased preferences for wild and a higher proportion of tiger bone in the glue. We estimated the direct price elasticity of demand based on Model 2. A 1% increase in the price of 100 g of tiger glue on average reduced the probability to purchase this product by 0.8%, suggesting that the demand for tiger glue was relatively inelastic to price changes.

The RPL model estimates showed a large standard deviation on the attribute wild, suggesting that there could be considerable heterogeneity in respondents' preference for source. To assess this heterogeneity, we estimated a LC model where all attributes except source and its interaction with legality are specified as identical across the classes, i.e., a discrete mixture model (Hess and Palma, 2019). In this model, class membership probabilities were solely determined by heterogeneity in the attribute wild, including its interaction with legality. We selected a model with two classes based on the AIC/n criterion. The LC model estimates showed substantial heterogeneity in preferences for source (see Table 1). Although members of both classes prefered wild over farmed tiger glue, individuals in Class 2 (31%) showed a much stronger preference for wild. A legally controlled trade in farmed tigers reduced preferences for wild tigers in both classes. However, only for Class 1 members (69%) was it sufficient to compensate for the strong preference for wild over farmed tiger glue. A legal trade also reduced preferences for purity.

Marginal willingness to pay for 100 g of tiger glue was calculated using the coefficients of Model 2. Intenders were on average willing to pay an additional VND 5.0 million (~US$ 220) for wild tiger glue, VND 19.0 million (~US$ 836) and VND 29.5 million (~US$ 1300) for 50% and 70% of tiger bone in the glue, respectively. The corresponding WTPs of consumers were VND 12.0 million (~US$ 528) for wild tiger glue, VND 35.4 million (~US$ 1560) for 50% and VND 53.8 million (~US$ 2370) for 70% of tiger bone in the glue. We present the marginal WTP of consumers and intenders for each product type in Table 2.

Respondents' attitudes toward tiger farming and a legal trade were generally positive. A majority of the respondents believed that tiger farming is the right thing to do (93%) and that a legally controlled trade in farmed tigers will reduce the price (90%) but also increase demand (88%). Respondents furthermore believed that buying tiger glue from legal sources can ensure quality and food safety (79%). Tiger glue consumers were more likely to agree with this statement than intenders ($F = 4.22$; $p < 0.05$). However, most of the respondents (92%) still stated that the quality of wild tiger glue is superior to farmed tiger glue. And only a small proportion (18%) found it easy to find cheaper alternatives to tiger glue with the same or better medicinal efficacy.

4. Discussion

Legalizing wildlife farming to avoid illegal poaching should only be considered if its impact on the market and consumer demand is clear (Bulte and Damania, 2005). Despite the urgency for wild tiger conservation, very few studies have been conducted on tiger glue consumers' behaviours, motivations, and the determinants of demand. Understanding preferences and trade-offs in the consumer's choice to purchase tiger glue and demand

elasticities is critical to generate insights for predicting the outcome of a legally controlled trade in farmed tigers as well as for the development of policies and behaviour change interventions (Veríssimo et al., 2020). Previous surveys in China and Vietnam were administered on respondents who were likely, in most cases, not actual consumers of tiger glue (Coals et al., 2020; Davis et al., 2020; Liu et al., 2015; Gratwicke et al., 2008). While these surveys are helpful in assessing the prevalence of using tiger products, it is important that consumer research focuses on individuals demanding these products rather than the general public (Dang, 2021; Dang Vu and Nielsen, 2021). This study is the first choice experiment to be conducted with a sample of actual tiger glue consumers and intended users, representing senior members of society with much higher monthly individual incomes than participants in previous studies. This implies that they fit the profile of users of these and other illegal luxury wildlife products better (see Dang, 2021).

Building upon the four conditions proposed by Biggs et al. (2013) required for a legal rhino horn trade to discourage poaching, Tensen (2016) developed five criteria that must be met to ensure that wildlife farming will benefit conservation. These include that: (i) legal products constitutes a substitute with the same quality, taste, and status conferring qualities; (ii) demand is met and does not increase to a threatening level when the trade is legalized; (iii) wildlife farming is more cost-efficient than poaching; (iv) wildlife farming does not use wild populations for restocking; and (v) laundering of illegal products into legal supplies is absent (Tensen, 2016). In the following, we will discuss our results in relation to these criteria.

Criterion one: The degree to which farmed tiger glue serves as a substitute for wild tiger glue depends on consumer preferences for the source and legality of the product. Our results confirm that consumers prefer wild over farmed tiger glue, resonating with findings of previous studies (Coals et al., 2020; Liu et al., 2015; Gratwicke et al., 2008). Unlike crocodiles and vicuñas, where farming has contributed to conserving wild populations (Moyle, 2013; McAllister et al., 2009; Macgregor, 2006), wild tigers are valued because consumers believe that wild tiger bones have higher medical efficacy thanks to living in natural habitats (Gratwicke et al., 2008). The strong preference for wild products is also considered one of main reasons leading to the failure of bear farming to reduce demand for wild bears in Vietnam (see Crudge et al., 2016). Our study supports these findings. Motivations for using wildlife products in traditional medicines (e.g., rhino horn and tiger bone) differ from those of use as fashion accessories and decoratives (e.g., crocodile skin, vicuña wool) (Kirkpatrick and Emerton, 2010). Exploring the heterogeneity of preferences, we found that a legal trade would shift the preferences of about two-thirds of the respondents (Class 1 members) to farmed products, for which they could be better ensured about quality, food safety, and legal compliance. While a legal trade reduced preferences for purity (i.e., respondents were less concerned about fake products), they were still not sure whether farmed products have the same medicinal efficacy. Addressing this question requires other methods such as lab testings and controlled clinical trials – including comparisons with known pharmaceutical treatments for the same ailments - that go beyond the scope of social science (see Dang Vu and Nielsen, 2021). If there is no significant difference in quality between farmed and wild tiger glue - and people still prefer tiger glue over pharmaceuticals - motivations may be driven by rarity and the status-conferring function of wild tigers (Rizzolo, 2021; Drury, 2011). Overall, unless consumer preferences change, farmed tiger glue is unlikely to substitute more than about two-thirds of wild tiger glue demand. Hence, this criterion is only partially met.

Criterion two: Given the negative effect of price on preferences for purchasing tiger glue, demand will generally increase if the price is reduced. In this case, demand must be understood as the quantity of tiger glue that consumers are willing and able to purchase at a specific price range over a given time period. As a legal trade may reduce the stigma of tiger glue usage, it may contribute to increasing demand (Fischer, 2004). Our respondents believed that a legal trade will increase demand. To what extent this increased demand can be met depends on the supply capacity of tiger farms. Unlike rhinos (Dang et al., 2021), tigers are technically easy to breed and have a high rate of reproduction in captivity (Ammann, 2015; Lapointe et al., 2007). Hence, it may be possible to expand tiger farm production to meet an increasing demand for farmed tiger glue in a legal trade. A legal trade in farmed tigers, on the other hand, will not eradicate the relatively price-inelastic illegal demand for wild-poached tigers. Therefore, this criterion is also only partially met, and poaching of wild tigers will likely continue.

Criterion three: It is universally argued that the cost of poaching a wild tiger is lower than the cost of raising a tiger in captivity (Gratwicke et al., 2008). Raising a tiger costs about US$4000 per year, of which about 75% is for feeding (Lapointe et al., 2007). Poaching only incurs low overhead costs (incl. snares, rifle rental), which can be less than US $20 in some range states (Gratwicke et al., 2008). Hence, producing a kilogram of tiger bones in captive-breeding facilities is 50%-300% more expensive than obtaining this from poaching a wild tiger (EIA [Environmental Investigation Agency], 2013). Although poaching and illegal production of tiger glue incur additional costs to avoid legal sanctions such as bribes and pay-offs (Abbott and Van Kooten, 2011), the profit outweighs the total cost given that an adult wild tiger contains 15–20 kg of bones which can be sold at a reported price range of US$1250–3750 per kilogram (Nowell & Xu, 2007). Our focus group discussions with tiger glue consumers and individuals involved in this trade revealed that the current black market price of tiger bone in Vietnam is about US $1000 per kilogram and that each kilogram of tiger bone can produce 300 g of tiger glue (70% of tiger bone in the glue). Thus a whole tiger skeleton with an average weight of 15 kg (US$15,000 for the skeleton) can produce 4.5 kg of tiger glue. Given the average black market price of US$12,000 per kilogram of tiger glue, one tiger carcass can generate about US$54,000 of revenue from producing tiger glue, not including the sale of its skin, teeth and claws. As other production and indirect costs (e.g., human resources, other ingredients, bribes) account for a maximum of US$9000 (based on insights from focus group discussions), tiger glue producers can make a profit of US$30,000 from one tiger skeleton – an ample profit given that the annual GDP per capita in Vietnam is just over US$2700 (World Bank, 2021). Legal trade may eliminate the risk of confiscation and cost of bribes but incur other costs to comply with new regulations such as management, quality control, certification and animal welfare including feeding, housing, and veterinary care, which is currently neglected (Tensen, 2016; Gratwicke et al., 2008). But tiger farming can take advantage of economics of scale given that tigers are prolific breeders and tiger farming only needs a retail price of US$20,000 per tiger to break even (Abbott and Van Kooten, 2011), which is much lower than the potential profit from producing tiger glue. Poaching furthermore requires that wild tigers still occur in sufficiently large numbers to facilitate poaching. Wild tiger populations are likely fully extirpated in Vietnam (Goodrich et al., 2015), and are probably soon to follow suit in the neighbouring countries of Cambodia, China (Stoner et al., 2016), and Lao PDR (Rasphone et al., 2019). Trafficking poached tigers from other source countries involves higher transportation costs and increased risk of confiscation and legal sanctions. Tiger farming in Vietnam may therefore become more cost-efficient than poaching wild tigers in the long term. Until then, the larger profit margin of illegal suppliers (combined with the preference for wild tigers cf. above) may enable traffickers to remain in business until wild tigers are all but extinct. Thus, this criterion is not fully met.

Criterion four: In theory, tiger farming does not require wild tigers for restocking, and this criterion can hence in principle, be satisfied (Lapointe et al., 2007). However, our results indicated a preference for wild tigers even if trade in farmed tigers is legalized. Captive-breeding facilities provide the opportunity for laundering wild tigers to meet this illegal demand in a legal trade (Stoner et al., 2016; Ammann, 2015). Laundering has occurred in the bear bile market in Vietnam (Crudge et al., 2016). Thus tiger farming can only be sustainable if it does not depend on wild populations and laundering is impossible (this is further discussed in the

last criterion). Our study has not investigated this aspect further.

Criterion five: Laundering wild animals through a legal trade have occurred in the trade of many species (Lyons and Natusch, 2011; Brooks et al., 2010; Nijman and Shephard, 2009; Stiles, 2004). Our results show that a legal trade would significantly shift consumer preferences to legal products from tiger farming. However, the legal trade will require certification and other regulatory costs to prevent laundering, which will drive up the price of legal products. And it cannot be guaranteed that laundering will be eliminated entirely given omnipresent corruptions in countries along the tiger trade chain (Crosta et al., 2017; Krishnasamy and Stoner, 2016). We found large heterogeneity in consumer preferences. Notably, higher-income consumers (Class 2 members) strongly prefer and are willing to pay more for wild tigers regardless of legality. Thus, laundering of wild tigers poached in nearby range states (e.g., India, Nepal, Indonesia, Malaysia, Myanmar, Thailand) cannot be avoided given the higher price of wild tiger glue in the black market (Gratwicke et al., 2008). This will likely lead to the parallel operation of two markets – a legal market for farmed tigers and an illegal market for wild tigers, as well as tigers illegally farmed under poor conditions (Tensen, 2016).

The discussion above indicates that, of the five criteria, only one may be satisfied (Criterion 4) and two partially met (Criteria 1, 2). Farmed tigers will likely not fully substitute wild products (Criterion 1), and poaching may be more cost-effective than farming tigers as long as tigers are still available in the wild (Criterion 3). Meanwhile, laundering cannot be entirely avoided (Criterion 5). These criteria should be considered relative factors that contribute to discourage poaching rather than absolute conditions to guarantee success of a legal trade. The illegal demand for wild tigers will not disappear with legal trade, and the survival of the remaining wild tiger populations will depend on effective law enforcement and conservation efforts. We agree with Gratwicke et al. (2008) that law enforcement and the establishment of new and better management of existing nature reserves harbouring wild tigers may remain the most effective solutions to conserve wild tigers. Our respondents generally showed a positive attitude toward tiger farming and a legally controlled trade, which resonates with Liu et al. (2015). However, substantial changes and efforts are needed for a legal trade in farmed tigers to be successful, as indicated by our evaluation of the results in relation to the five criteria above. First, tiger farms must be well regulated with strongly enforced requirements for breeding conditions and living environment (e.g., semiwild environment, space requirement per tiger), management of the gene pool and animal welfare, including food, veterinary care and control of zoonotic diseases based on a certification scheme for farms that cannot be bypassed. Second, law enforcement should be strengthened to prevent illegal farming, poaching and laundering of wild tigers (e.g., documentation of farmed tigers, through microchip identification systems and genetic identification). Although the illegal trade in tiger products has been banned as per the Criminal Code of Vietnam (see Law No. 100/2015/QH13, which was amended in 2017 and took effect from January 1st 2018), and a national strategy to conserve tigers developed for the period 2014–2022 (see Decision No. 539/QĐ-TTg), the implementation of those are not well managed (Davis et al., 2020; The National Assembly of Vietnam, 2019). And third, behaviour modification campaigns should continue to further shift consumer preferences to legally farmed products and pharmaceutical alternatives to tiger glue made from legal and sustainable ingredients.

Despite concerted efforts to reduce the demand for tiger products in Asia and elsewhere, with initiatives ranging from government publicity about legal sanctions to behaviour modification campaigns (e.g., ENV, 2019; TRAFFIC, 2019; Saypanya et al., 2013; Broad and Damania, 2010), it is unclear whether these initiatives have been effective due to insufficient evidence about their impact on consumer motivations and behaviours (Mills, 1997). Our results provided important insights for the design of behaviour modification campaigns indicating that these should focus on middle-aged and wealthy individuals who have used or intend to use tiger glue. Campaigns can highlight the prevalence of low-quality (low proportion of tiger bone in the glue) or fake tiger products (no tiger bone in the glue) in the market as a warning to consumers. And campaigns must be designed to enable impact assessment, for instance, through a randomized controlled trial approach.

5. Conclusions

Our study shows that consumers prefer and are willing to pay more for wild tiger glue. They also prefer a higher proportion of tiger bone in the glue, i.e., better quality. At the same time, there is disutility of the illegal aspect. Legal trade will significantly shift preferences to farmed tiger glue from legal supplies for about two-thirds of the consumers. Still, the demand for illegal wild tigers will not be eradicated, leading to the possible parallel operation of two markets – a legal market for farmed tigers and an illegal market for wild tigers. The demand for farmed tiger glue may be met by expanding tiger farming, which is feasible thanks to the high reproduction rate of tigers and because tigers are relatively easy to breed in captivity. However, poaching will likely continue regardless of the establishment of a legal trade. And the conservation of the remaining wild tigers will depend on the acceptance of alternatives to tiger glue, law enforcement and demand management efforts, and the protection of habitat in nature reserves. Our study reveals the typical profile of tiger glue consumers and suggests that behaviour modification campaigns designed to manage demand should focus on individuals demanding tiger glue, especially those who already have experience using this product, and be designed to enable impact assessment.

Authors' Contributions

All authors contributed to the conceptualization of the project and the development of the survey and sampling procedures. The authors jointly designed the study. J.V.N., K.G., and D.V.H.N. led the fieldwork, analyzed 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 analyzed in this study is available at the University of Copenhagen's Electronic Research Data Archive (ERDA) at https://doi.org/10.17894/ucph.f1f386ad-d439-43e8-93c3-0c62fdbc5d1e

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 that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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