

Heterogeneous impacts of large carnivores on hunting lease prices

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ARTICLE INFO

Keywords:

Large carnivores
Unconditional quantile regression
Conditional quantile regression
Hunting lease prices
Wildlife management
Hedonic pricing

JEL codes:

Q51
Q57

ABSTRACT

Notwithstanding their crucial role in ecosystem functionality, large carnivores generally entail economic costs to hunters due to competition for the same prey. This cost could potentially vary depending on carnivore density and the game hunting values at stake. We estimate a hedonic price model applying the unconditional quantile regression method in order to investigate the impact of large carnivores along the distribution of hunting lease prices in Sweden. We compare these impacts with those obtained from conditional quantile regressions, as well as from ordinary least squares estimations. Based on the unconditional quantile estimates, our results indicate that wolf, lynx and bear can exert a negatively significant effect in the middle range of the outcome distribution, while no significant impact is found in the lower quantiles. For the statistically significant quantiles, the average marginal implicit price of an additional wolf territory in the study area is around 3.35 million Swedish kronor (SEK) per year, namely 358 thousand Euros (EUR). This corresponds to an annual reduction in the mean hunting lease price per hectare by 21% in the municipality where the territory is established. Similarly, an additional lynx family group entails an average marginal implicit price of SEK 3.55 million (EUR 379 thousand) per year, and an additional brown bear individual entails an average marginal implicit price of nearly SEK 110 thousand (EUR 11.6 thousand) per year. The corresponding impact on the mean hunting lease price per hectare is a reduction by 22.4% and 0.6% for an additional lynx family group and an additional brown bear individual, respectively, in the municipality where the establishment occurs. Results can be useful for policies targeting the spatial distribution of large carnivores.

1. Introduction

The conservation of viable large carnivore populations in human-populated areas has engendered major challenges and public debate for wildlife management and biodiversity conservation (Treves et al., 2006; Chapron et al., 2014). Carnivore-human coexistence has given rise to social, economic and political conflicts, which require balancing local concerns for the potential negative effects of carnivores with societal apprehensions towards saving endangered species (Sjölander-Lindqvist et al., 2015). Conflicts occur insofar carnivores predate on livestock, hence affecting farmers and reindeer herders (Treves et al., 2006; Widman and Elofsson, 2018), and the magnitude of livestock damages vary with carnivore and livestock density (Widman and Elofsson, 2018). Moreover, large carnivores negatively affect hunters by reducing the game available to harvest, which in turn decreases landowners' revenue from leasing out their property to hunting activities (Sjölander-Lindqvist, 2015; Mensah et al., 2019; Lozano et al., 2020).

The impact on hunting activities can be expected to vary, given that large carnivores exert a differential effect on game species' abundance contingent on the population density of carnivore and prey species (Sand et al., 2012), and depending on the productivity of the ecosystem (Melis et al., 2009).

In order to address the variations in large carnivore-human conflicts across space, carnivore policies often include some kind of zoning, which aims to reduce the spatial overlap between large carnivores' distribution areas and affected human activities (Linnell et al., 2005). Such separation can be achieved by for example control of carnivore population density outside the designated carnivore zone, or removal of the potentially conflicting activities from carnivore range. The designation of carnivore zones is usually made with an aim to minimize livestock damages and human-safety issues (Linnell et al., 2005; Skogen, 2015; EPA, 2014a, 2014b, 2014c), but the impact on hunting activities is not taken into account. However, the economic impact of carnivores on hunting activities can be large compared to that on the livestock sector

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<https://doi.org/10.1016/j.landusepol.2020.105215>

Received 30 June 2020; Received in revised form 15 October 2020; Accepted 27 November 2020

Available online 16 December 2020

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(Mensah et al., 2019). Moreover, there are often strong linkages between carnivores' impact on hunting activities, and attitudes to carnivore conservation among people in rural areas (Skogen, 2015). Therefore, ignoring the variation in carnivore impact on hunting activities could undermine acceptance of carnivore zoning policies, and thus increase the risk that carnivore conservation goals are not met.

In the earlier economic literature on large carnivores, some empirical studies estimate the average (Asheim and Myrsetrud, 2004; Bostedt and Grahn, 2008) or average marginal (Mensah et al., 2019) cost per carnivore due to livestock and game depredation; while Widman and Elofsson (2018) measure the variation in marginal cost across regions. However, no earlier study has recognized that the impact of a given carnivore species on hunting could vary across different market price segments. This is a shortcoming, as there are strong indications that the market for hunting leases is segmented, with contracts between land owner and hunters varying with the scope, scale, duration, and conditions for hunting (Lundhede et al., 2015; Mensah and Elofsson, 2017).

The purpose of this study is to investigate how the marginal impact of large carnivores on hunting lease prices in Sweden varies across different segments of the hunting lease price distribution. We conjecture that a varying impact along the price distribution could be expected due to the variations in impact of carnivores on prey species, and the variation in the demand for hunting. Identification of conditions where the impact on lease prices is high, indicating that the hunting-carnivore conflict is particularly strong, is important from a policy perspective as wildlife managers have the explicit task to undertake measures to avoid such conflicts. Knowledge on the variation in impact on hunting lease prices is also valuable for policy decisions on targets for the geographical distribution of large carnivores.

To analyze whether the economic impact of carnivores on hunting values differs across multiple valuation segments we apply the quantile regression (QR) framework. This framework is used to estimate the marginal effect of an explanatory regressor across different segments of the dependent variable in order to provide more detailed information on the variation in impact of the explanatory variable (Koenker and Hallock, 2001). Economic studies have applied the conditional quantile regression (CQR) approach to find heterogeneous effects in the response variable (Koenker and Basset, 1978), with several applications to hedonic valuation of environmental goods and bads such as, e.g., environmental amenities on farmland (Uematsu et al., 2013), flood risk (Rajapaksa et al., 2017), and wildfires (Mueller and Loomis, 2014). In these studies, the marginal effects are generally compared with the average effect across the whole price distribution yielded by ordinary least squares (OLS) estimations. However, when estimating CQR, the quantiles and thus the interpretation of the coefficients vary once explanatory variables are added to (or removed from) the model (Porter, 2015). As a result, unconditional quantile regression (UQR) has become increasingly used as a more appropriate method for hedonic studies to address policy relevant questions in the presence of multiple covariates (Firpo et al., 2009; Borah & Basu, 2013; Peeters et al., 2017). UQR estimates can be interpreted in a similar fashion as OLS in the sense that the effect on each quantile can be generalized to the entire (quantile) population, and the interpretation of the coefficients is not conditional on the values of the covariates. Because we are interested in the marginal impact of carnivores on different segments of the overall distribution of hunting lease prices, the unconditional quantile method provides a more suitable technique than CQR and OLS. In addition, we adopt a functional form of the hedonic price function in which marginal implicit prices can be determined for each unconditional quantile irrespective of the values taken by the dependent variable, i.e. the lease price, within the quantile.

Our analysis reveals heterogeneity in the marginal effect of large carnivores on hunting lease prices. Results show that the largest impact occurs in the percentiles close to the median, whereas the lower tail of the lease price distribution is presumably unaffected by any of the three species.

This paper is structured as follows. In Section 2, we propose and develop the estimation of the hedonic-price model by applying the quantile regression framework. Section 3 describes the data of the study. Section 4 presents the estimation results and marginal implicit prices for each carnivore species, and Section 5 provides concluding remarks. Quantitative information aimed at facilitating the reading and interpretation of the empirical results is provided in an appendix at the end of the paper and in the supplementary material.

2. Methods

2.1. Proposed empirical model

Hedonic pricing is a revealed preference method that has been widely used to decompose the prices of a property or good into its constituent characteristics (Rosen, 1974; Taylor, 2003). In a competitive market, consumers maximize utility by bidding the minimum price for each characteristic, while sellers try to ask for the profit maximizing price (Livengood, 1983; Lundhede et al., 2015). Thus, the market equilibrium is reached when bid and offer prices converge (Palmquist, 1989). In Sweden, more than 300 000 hunters have invested about EUR 50 million per year in hunting (Mattson et al., 2008); therefore, the Swedish hunting lease market is sufficiently large to assume sellers (landlords) and bidders (hunters) to be lease price takers. The bidding price that hunters are willing to pay arises from the maximization of a utility function that includes attributes primarily related to harvest success and hunting experience (Messonnier and Luzar, 1990; Zhang et al., 2006). The selling price asked by landowners comes from the profit maximization that accounts for hunting site attributes, diversity of game species and the costs of the services provided (Pope and Stoll, 1985; Lundhede et al., 2015). Hence, the equilibrium lease price embodies costs and values for hunters and landowners, and it is determined by supply and demand for the use of hunting grounds with various constituent attributes (Mensah and Elofsson, 2017).

We formulate a hedonic price model to estimate the effect of the presence of wolf (*Canis lupus*), Eurasian lynx (*Lynx lynx*) and Eurasian brown bear (*Ursus arctos*) on hunting lease prices controlling for other attributes:

$$P = \alpha + \beta \ln(1 + C_j) + \gamma G + \varepsilon, \quad (1)$$

where P is the rental price per hectare paid by a hunting team and C_j is the population density of each carnivore species j , with $j = \{\text{wolf, lynx, brown bear}\}$. The carnivore index C_j is taken in logarithm plus one unit, in order to avoid undefined values for those hunting areas without carnivore population ($C_j = 0$). G is a vector of attributes that, according to the literature, influence hunting lease prices from the demand or supply side (Livengood, 1983; Zhang et al., 2006; Little and Berrens, 2008; Lundhede et al., 2015; Mensah and Elofsson, 2017; Lozano et al., 2020): Size of the hunting area, number of team members, human population density in the municipality, distance to the nearest biggest city¹, municipality income per capita², land ownership (dummy = 1 if

¹ The distance to the largest nearest city is included because the demand for hunting grounds is expected to be higher in grounds closer to large urban areas (Little and Berrens, 2008). Danish hunters also contribute to the demand for hunting plots in Sweden, in particular in the south. The Danish hunters almost exclusively enter Sweden via Malmö, hence the distance to large cities accounts also for the demand from those.

² This covariate accounts for socioeconomic and structural characteristics of a municipality. A municipality with higher income can be inferred to produce a higher demand for hunting plots, which as a result, can increase the hunting lease price (Mensah and Elofsson, 2017). On the other hand, there might be fewer alternative recreation opportunities in low income, rural municipalities, which could also increase the demand for hunting plots. Hence, the direction of the impact is not *a priori* given.

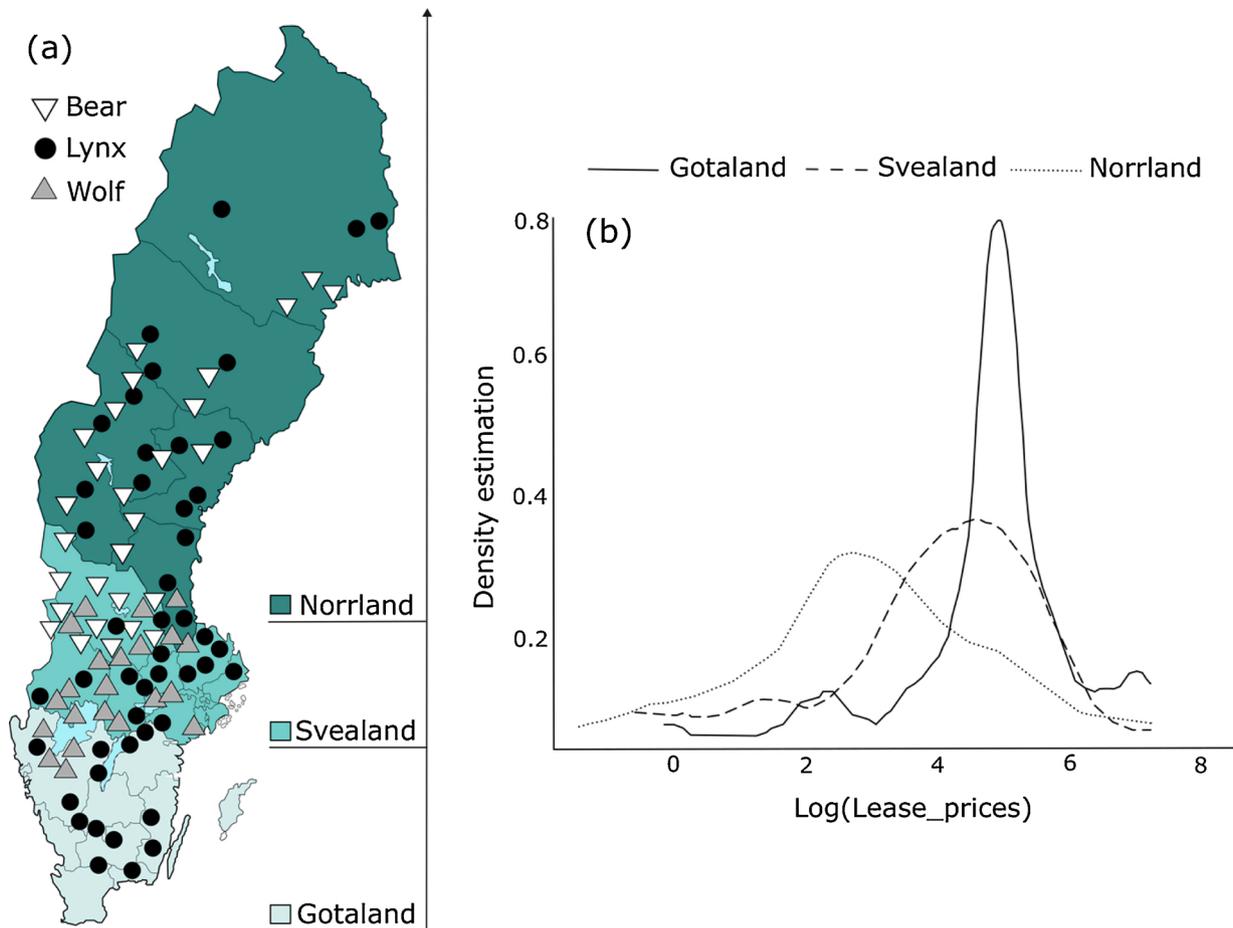


Fig. 1. (a) Map of Sweden with the distribution of carnivores per region. (b) Distribution of (logarithmic) hunting lease prices (SEK ha⁻¹ yr⁻¹) per region. **Notes:** The map pins the municipalities with high population density for each of the carnivore species in the three regions Norrland, Svealand, and Gotaland. The markers are based on the carnivore indexes. The density graph on the right hand side illustrates the disparity of hunting lease prices across the different regions. Gotaland is the region with highest hunting rental prices and Norrland the cheapest.

the ground belongs to a forest company), carnivore quota, and two proxies for the abundance of game; forest productivity and snow depth.

The two proxies for abundance of game, forest productivity and snow depth indicate the potential harvest in the absence of large carnivores³. The use of such proxies instead of bag rates is motivated by the fact that bag rates are likely to be negatively affected by the presence of large carnivores. Hence, using bag rates in the estimations might substantially bias the estimation of the impact of the carnivore abundance variable on the hunting lease price. For example, Mensah et al. (2019) show that the impact of lynx abundance on hunting lease prices occurs solely through the reduction in the bag rate. The inclusion of proxies in the model allows for exclusion of the bag rate without having an omitted variable bias. The use of proxies, which follow Lozano et al. (2020), permits us to untangle the effect of carnivores from other attributes affecting hunting lease prices.

The first game abundance proxy, snow depth, measures the winter severity: intense winters with high snow depth are expected to reduce game abundance because of hindered mobility, reproduction and survival (Mysterud et al., 1997; Lundmark and Ball, 2008). In addition, winter conditions may affect ungulate dynamics in the long term. The second proxy, forest productivity, relates to habitat conditions affecting ungulate game distribution. High-productivity forests with fertile soils

³ One can note that it is common in the literature to use harvest as a proxy for game populations (e.g., Cattadori et al., 2003), here we assume the two variables are strongly correlated.

may increase game abundance because of better habitat conditions for wildlife (Bjørneraas et al., 2012; Meilby et al., 2006). The two proxies for game abundance are therefore relatively good indicators of the abundance and spatial distribution of moose (*Alces alces*) and roe deer (*Capreolus capreolus*) in the country, although locally specific habitat conditions and the distribution of infrastructure can also matter⁴. Both moose and roe deer are ungulate game, which are common prey of the three carnivores analyzed in this study. Wolf preys mainly on moose (Sand et al., 2016), lynx preys primarily on roe deer when available (Andrén and Liberg, 2015), and brown bear can often prey on moose calves after hibernation (Dahle et al., 1998). The disturbance ϵ represents all the uncontrolled characteristics in the model. Finally, α , β and γ are parameters to be estimated, of which β is expected to be negative and of crucial relevance to this study⁵.

Although the semi-log functional form has been commonly used to

⁴ Reliable and relevant data on habitat characteristics and infrastructure are difficult to retrieve from a survey. Another factor that might affect moose harvest rates is the moose management regulations, where harvest rates are decided upon at the regional level, e.g., for the Moose Management Areas). However in practice, the regulation seems not to be binding given the large deviations from targeted harvests in combination with the absence of sanctions for noncompliance.

⁵ The parameter β is defined for each of the j carnivore species, i.e., the notation should be β_j . However, we have removed the subscript j to avoid notational cluttering in the subsequent expressions.

estimate parametric hedonic price models (Livengood, 1983; Hussain et al., 2007; Munn and Hussain, 2010), no particular model specification has been proven to be superior to another (Owusu-Ansah, 2011). Besides, hedonic theory does not pose constraints on the choice of functional form (Cropper et al., 1988). The specification of Eq. (1) allows us to find the marginal implicit price of each carnivore for different population densities:

$$\frac{\partial P}{\partial C_j} = \frac{\beta}{1 + C_j} \quad (2)$$

This implies that the marginal implicit price is not a function of the dependent variable (price) as would otherwise be the case if having a log-linear or log-log specification.

2.2. Model estimation

Ordinary Least Squares (OLS) coefficients provide an interpretation of the effect of a regressor on the mean of the dependent variable Y . An advantage of using OLS is that the law of iterated expectations (LIE) allows to measure the impact β of an explanatory variable X on the conditional, and also, the unconditional average of the outcome variable Y .

Nevertheless, OLS results cannot be used to explain changes along the entire distribution of the dependent variable. If the impact of an explanatory variable on the outcome variable is different for different segments of the distribution of Y , the use of the conditional quantile regression (CQR) seems in principle to be more appropriate (Koenker and Bassett 1978). CQR shows the impact of a covariate on different quantiles of the dependent variable, however it only provides consistent estimates for the conditional distribution of Y . Since the LIE is not applicable to the estimates of CQR, the effect β on the τ th conditional quantile of the dependent variable cannot be generalized to the population level.

To that extent, unconditional quantile regression (UQR) outperforms CQR as it obeys the LIE and allows to find the marginal effect of X on the unconditional distribution of the outcome variable irrespective of the other covariates. To estimate the UQR we use the method developed by Firpo et al. (2009) which defines a transformation of the dependent variable on the covariates. This transformation is known as the Influence Function (IF) and it is used to calculate the effect of an additional observation on the statistic of a specific quantile:

$$IF(Y; q_\tau) = \frac{\tau - I(Y \leq q_\tau)}{f_Y(q_\tau)}, \quad (3)$$

where q_τ is the statistic of the τ th quantile, $f_Y(q_\tau)$ is the probability density function of the outcome variable Y evaluated at q_τ , and $I(Y \leq q_\tau)$ is an indicator function equal to 1 if $Y \leq q_\tau$. A re-centered influence function (RIF) can be obtained by adding the quantile statistic to the IF:

$$RIF(Y; q_\tau) = q_\tau + IF(Y; q_\tau) \quad (4)$$

By regressing the conditional expectation of the RIF on the explanatory variables X , the RIF model can be viewed as a UQR (Borah & Basu, 2013):

$$E[RIF(Y; q_\tau)|X] = m_\tau(X) \quad (5)$$

The marginal effect on the τ th unconditional quantile of a small change in the distribution of a (continuous) explanatory variable, holding everything else constant, is given by:

$$\beta_\tau = E \left[\frac{dm_\tau(X)}{dX} \right] \quad (6)$$

To implement the UQR method with our proposed hedonic price model in Equation (1) and find the associated partial effects (i.e. marginal implicit prices) we proceed as outlined in Firpo et al. (2009). First,

we estimate the RIF of the τ th quantile. Second, we run an OLS regression of the estimated RIF⁶ on the covariates X (known as RIF-OLS regression) in order to obtain the estimated β_τ coefficients that will allow us to calculate the marginal implicit prices for each carnivore⁷.

Based on expression (6), we differentiate the unconditional expectation of the model (1), $(m_\tau(X))$, with respect to each carnivore index to find the marginal implicit price at the τ th quantile. Hence, the marginal implicit price of each carnivore index in values per hectare is given by:

$$\frac{\partial m_\tau(P)}{\partial C_j} = \frac{\beta_\tau}{1 + C_j} \quad (7)$$

The only difference between expressions (2) and (7) is that the latter corresponds to the (heterogeneous) marginal implicit price per quantile whereas the former calculates an average marginal implicit price based on the parameter β . In both cases, the marginal implicit prices vary with the carnivore population density index C_j .

3. Data

Hunting ground specific data were obtained from a survey. The sample was randomly selected from the official Swedish Hunters Registry. Hunters were asked questions on the rental price of the hunting ground, the number of members in the hunting team, the size of the hunting ground, the hunting bag, and whether the land was owned by a forest company or not. The questionnaire further asked questions on attitudes to hunting ethics, illegal hunting, wildlife management and policy, and wolf conservation. The survey was first sent out by mail in May 2016 and was followed by two reminders. To encourage participation, a hunting trip worth SEK 7 500 (EUR 802)⁸ was drawn out among the respondents. The total number of surveyed hunters was 2014 and the questionnaire was responded to by 957 hunters (i.e. 47.5% response rate). Out of the answered surveys, 323 responded to the question on hunting lease price, and were used for the present study. A likely reason for the low response rate on the lease price question is that prices are seen as private and sensitive information.

Concerning the hunting lease price (i.e., the dependent variable), the survey asked hunters the price per hectare and year (P) that they actually pay to lease the right to hunt in their most frequented hunting site for the 2014/2015 season. Hunting grounds with lease prices reported by the respondents are located in 154 municipalities in Sweden out of the total 290 municipalities in the country (Fig. A1, Appendix). Following experts' appraisal, we take lease prices above SEK 1 000 per hectare and year (93.5 EUR ha⁻¹ yr⁻¹) as anomalous observations in the dataset. Five survey answers fall beyond this threshold, thus we set these observations to the 98th percentile of the data, and perform a 98% winsorization in order to reduce the effect of outliers (Rupert, 2006). High and low prices of hunting land can be found in all parts of Sweden, but there is a tendency for higher prices further south in the country (Fig. 1(b)).

Wolf, lynx and bear presence are measured, respectively, as a population density index in the municipality, earlier used in Mensah et al. (2019) and Lozano et al. (2020). Carnivore data was collected from the database Rovbase (www.rovbase.no). The main monitoring units are

⁶ Because q_τ and $f_Y(q_\tau)$ are population statistics, they are actually unknown. Therefore, the estimated RIF is calculated with the sample statistics: $\widehat{RIF}(Y; \hat{q}_\tau) = \hat{q}_\tau + \frac{\tau - I(Y \leq \hat{q}_\tau)}{\hat{f}_Y(\hat{q}_\tau)}$

⁷ For a discussion on the difficulty of extracting marginal quantiles from a conditional quantile linear model see Angrist and Pischke (2009) pp. 283.

⁸ Exchange rate is 9.35 SEK per EUR, calculated as the average for years 2014 and 2015 according to Central Bank of Sweden (Sveriges Riksbank).

Table 1
Descriptive statistics (= 323 observations).

Variable	Description	Mean	Std. Dev.	Minimum	Median	Maximum
Hunting lease price	Hunting lease price (SEK ha ⁻¹ yr ⁻¹) → <i>Dependent variable</i>	96.68	168.19	0.17	50	1 000
	Hunting lease price (SEK ha ⁻¹ yr ⁻¹) by region:					
	Gotaland (South)	153.05	200.78	0.6	100	1 000
	Svealand (Middle)	72.36	113.9	0.38	40	1 000
	Norrland (North)	47.16	147.15	0.17	10.98	1 000
Area	Size of hunting area (hectares, ha)	2 727	6 401.84	4	1 005	80 000
log(area)	Log-transformed size of hunting area	6.89	1.54	1.39	6.91	11.29
Members	Number of hunting team members	18.03	28.39	1	11	350
log(members)	Log-transformed number of members per hunting team	2.55	0.8	0.69	2.48	5.86
Forest_prod	Forest productivity (m ³ /ha)	6.21	1.62	2.8	6.8	8.3
Snow_depth	Snow depth (m)	0.11	0.14	0	0.05	0.6
Wolf index	Wolf index	0.2	0.45	0	0	2.29
Lynx index	Lynx index	0.16	0.16	0	0.12	0.77
Bear index	Bear index	0.12	0.24	0	0.16	1.73
Bear_quota	Bear quota	17.72	25.88	0	36	67
Popdens	Municipality population density (population per km ²)	31.16	32.68	0.2	19.8	176.7
log(popdens)	Log-transformed municipality population density	3.44	3.49	-1.61	2.99	5.17
Income_pc	Municipality income per capita (SEK 1 000 per year)	51.28	218.86	1.24	13.47	2 415.25
log(income_pc)	Log-transformed municipality income per capita	3.94	5.39	0.22	2.6	7.79
Distance	Distance to the nearest big city (km)	256.68	216.27	21.29	183.98	942.69
log(distance)	Log-transformed distance to the nearest big city	5.55	5.38	3.06	5.21	6.85
Company	Land ownership (dummy = 1 for forest company)	0.26	0.44	0	0	1

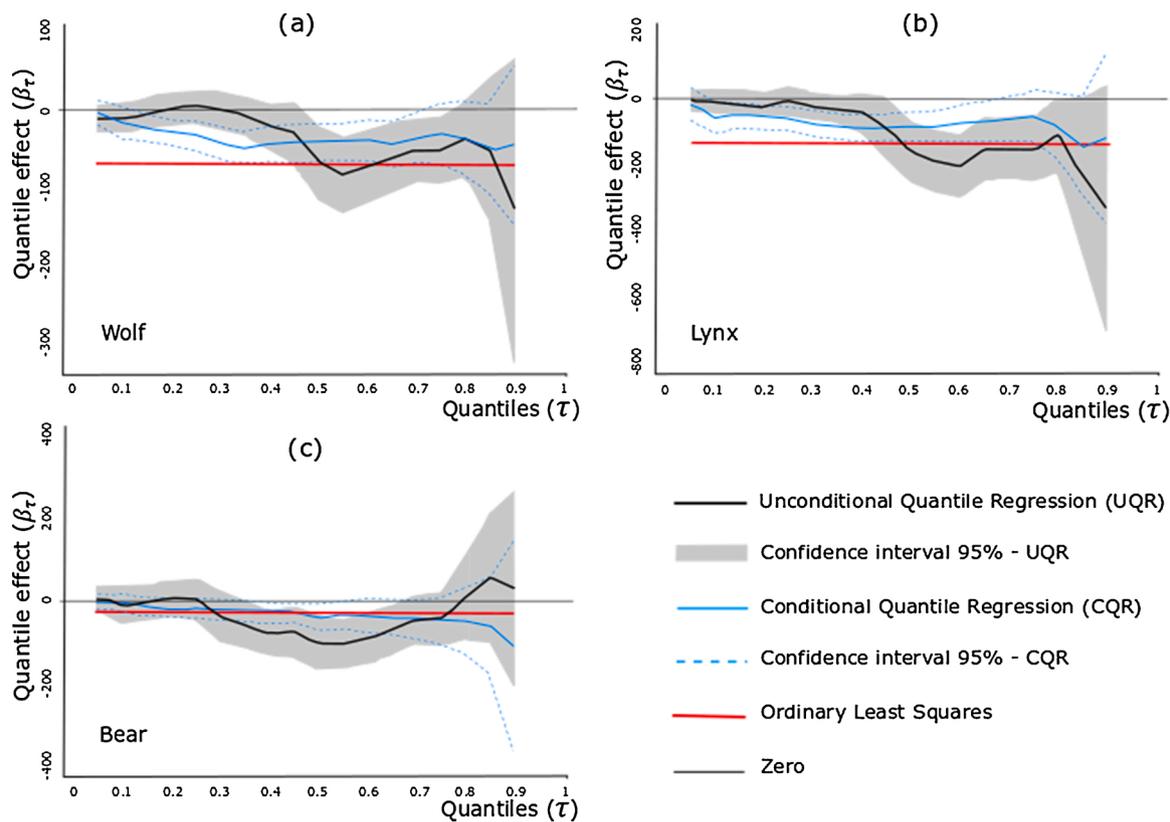


Fig. 2. Quantile plots for the estimated coefficients of (a) wolf, (b) lynx and (c) bear.

wolf family groups (i.e., a pair with offspring) and pairs (i.e. territorial [scent-marking] pairs), and lynx family groups⁹ (i.e., a female with young of the year). The monitoring data consists of coordinates for the center point of all observations documented within the monitoring program assumed to belong to the same family group or pair (Anon,

⁹ One monitored lynx family group represents about 5.48 ± 0.40 individuals (the family group, as well as unmonitored subadults and adult males and barren females (Andrén et al., 2006).

2014; Svensson et al., 2014). The wolf index provides an approximation of wolf density by creating buffer zones of 1.000 km² around the center point of a wolf pack (Mattison et al., 2013). A buffer zone includes the home range of a wolf territory, i.e. the area where animals frequently reside, feed, defend and reproduce. Buffer zones of different wolf packs can overlap, and one buffer zone can spread over more than one municipality. In order to obtain a measure of wolf presence for each municipality, we divide the area of wolf buffer zones by the total area of the municipality. Likewise, the lynx index is calculated in a similar fashion by creating buffer zones of 320 km² around the center point of a lynx

Table 2

Estimation results for OLS, CQR and UQR with the hunting lease price per hectare and year (SEK ha⁻¹ yr⁻¹) as the dependent variable.

Dependent variable:	OLS	Conditional Quantile Regression (CQR)					Unconditional Quantile Regression (UQR)				
		Q_10	Q_40	Q_50	Q_60	Q_90	Q_10	Q_40	Q_50	Q_60	Q_90
<i>logarea</i>	-39.36** (15.77)	-7.36** (3.48)	-9.70*** (2.99)	-11.98*** (4.62)	-15.13** (7.10)	-50.66 (34.17)	-4.12*** (1.34)	-5.45** (2.74)	-11.13** (4.31)	-14.53*** (5.30)	-87.66* (46.43)
<i>logmembers</i>	18.94 (13.65)	-0.15 (2.68)	2.23 (2.36)	3.39 (3.07)	4.73 (4.81)	22.62 (21.71)	-1.22 (3.06)	1.20 (3.55)	1.30 (5.59)	7.24 (6.66)	75.23 (48.05)
<i>forest_prod</i>	13.79 (9.78)	4.57 (4.49)	10.35*** (3.27)	15.25*** (3.13)	13.81*** (3.99)	30.23 (20.48)	-1.79 (2.61)	8.71* (4.50)	22.68*** (7.24)	27.18*** (7.84)	42.10 (27.35)
<i>snow_depth</i>	230.07* (130.55)	37.42 (28.53)	-12.86 (25.28)	7.03 (24.73)	37.31 (28.87)	324.01 (231.33)	-16.02 (27.17)	-56.64 (37.39)	22.55 (56.89)	56.03 (64.65)	882.25* (469.41)
<i>log(1+wolf)</i>	-70.38*** (20.71)	-16.80 (10.65)	-44.02*** (11.33)	-41.30*** (12.42)	-39.43*** (12.64)	-44.43 (51.34)	-10.10 (8.98)	-21.04 (14.98)	-67.61*** (23.36)	-72.07*** (23.36)	-131.14 (98.82)
<i>log(1+lynx)</i>	-135.92** (65.24)	-56.39** (21.95)	-89.51*** (19.89)	-84.76*** (21.81)	-72.66** (29.33)	-117.99 (115.34)	-6.99 (17.71)	-42.94 (27.33)	-159.15*** (41.37)	-202.95*** (46.68)	-332.09* (191.86)
<i>log(1+bear)</i>	-27.0592 (41.67)	-3.79 (11.04)	-26.12* (14.37)	-37.05** (14.62)	-33.98* (19.92)	-109.82 (113.76)	-5.60 (21.24)	-75.90*** (26.44)	-100.74*** (31.99)	-87.86*** (30.34)	30.48 (134.68)
<i>bear_quota</i>	204.50* (12.88)	70.23* (40.62)	59.71 (72.11)	64.06 (117.26)	112.82 (165.19)	963.98* (562.23)	23.35 (34.73)	62.00 (62.34)	140.68* (82.20)	154.51 (97.78)	377.18 (770.68)
<i>log_popdens</i>	-7.33 (12.18)	-0.74 (3.12)	-5.90* (3.14)	-5.54 (4.16)	-2.93 (5.46)	-19.74 (24.91)	2.34 (3.06)	-6.62 (4.47)	-6.81 (6.48)	-12.23* (6.63)	16.85 (35.10)
<i>log_incomepc</i>	0.64 (9.39)	1.58 (2.14)	-2.82 (3.04)	-2.31 (4.11)	2.12 (5.25)	-6.02 (22.90)	-0.40 (2.20)	-2.13 (3.27)	-1.04 (4.75)	-1.74 (5.52)	43.73 (28.35)
<i>log_distance</i>	-44.64 (28.71)	-9.80 (7.72)	-10.45* (6.08)	-4.84 (8.29)	-17.94 (12.37)	-57.62 (70.49)	-0.83 (3.51)	-18.08*** (6.59)	-27.86** (12.25)	-23.21 (15.31)	-76.99 (70.65)
<i>forest_company</i>	3.58 (18.78)	-3.99 (5.31)	4.12 (4.67)	3.11 (4.16)	0.54 (4.72)	-4.18 (29.18)	-5.29 (5.37)	-5.98 (6.64)	-3.22 (10.41)	12.99 (13.43)	3.55 (44.35)
<i>_cons</i>	487.08*** (208.63)	94.80* (56.87)	146.41*** (53.99)	104.38 (68.53)	189.22** (92.74)	628.66 (553.45)	51.79 (34.35)	146.89** (61.34)	187.98* (106.45)	181.80 (124.15)	558.89 (582.68)

Notes: UQR and CQR estimations are obtained with bootstrapped standard errors of 500 replications (shown in parentheses). Standard errors of OLS estimations are clustered on a municipality level.

family group (Aronsson et al., 2016). Hence, the lynx index equals the sum of the areas of lynx buffer zones divided by the area of each municipality. On the other hand, the brown bear index is not based on buffer zones but on the identification of bear individuals from scat surveys (DNA inventories), and it reflects the relative bear density in each municipality (Kindberg et al., 2011).

A map of the distribution of the large carnivores can be found in

Fig. 1. The map shows that the lynx is spread throughout the country, while the brown bear is found in the middle and northern parts of the country, and the wolf is almost exclusively found in the middle part. The spatial distribution of the species is affected by the carnivore management policy. Wolves are subject to stringent population control in the northern part of the country in order to avoid conflicts with reindeer herding (EPA, 2014a), and is often subject to culling in the southern part

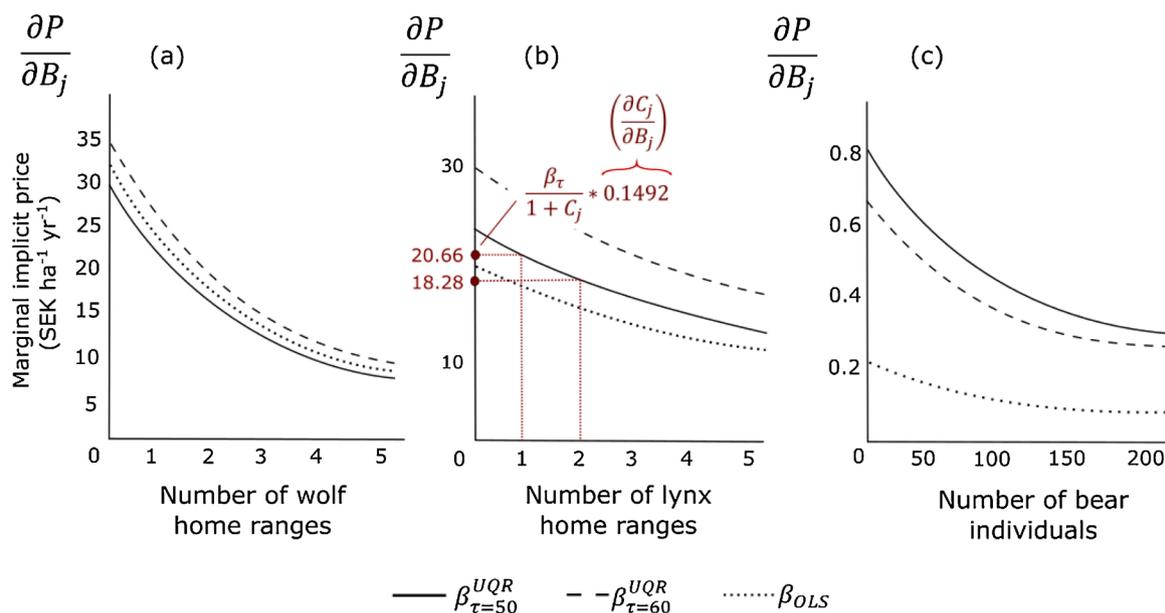


Fig. 3. Marginal implicit prices in SEK per hectare and year, as a function of additional wolf home ranges, lynx home ranges or bear individuals. The prices apply for the municipality where the carnivore home range or individual is established.

Notes: The continuous and dashed curves correspond to the partial effect obtained from two different unconditional quantiles, 50th and 60th respectively, and the dotted line relates to OLS. The different curves for different (unconditional) quantiles reflect the heterogeneous effect of carnivores on lease prices. Moreover, this heterogeneity also pertains to the difference between the OLS and UQR curves. As an example, Fig. 3b shows in red font the marginal implicit prices at the median quantile that corresponds respectively, to one additional lynx territory, and to two additional lynx territories.

Table 3
Marginal implicit prices of one additional carnivore territory or individual for the statistically significant (unconditional) quantiles.

Carnivore species	Range of unconditional quantiles that are significant (at 5% level)	Marginal implicit prices in municipality of establishment (SEK ha ⁻¹ yr ⁻¹)	Average marginal implicit price in municipality of establishment (SEK ha ⁻¹ yr ⁻¹)	Marginal implicit price (million SEK territory ⁻¹ yr ⁻¹ for wolf and lynx, million SEK individual ⁻¹ yr ⁻¹ for bear)	Average marginal implicit price per year (million SEK territory ⁻¹ yr ⁻¹ for wolf and lynx, million SEK individual ⁻¹ yr ⁻¹ for bear)
	(1)	(2)	(3)	(4)	(5)
Wolf	48 th - 77 th	14.1 - 26.6	20.3	2.3 - 4.4	3.35
Lynx	46 th - 77 th	15.7 - 27.7	21.7	2.6 - 4.5	3.55
Bear	34 th - 65 th	0.46 - 0.86	0.66	0.07 - 0.14	0.11

Notes: Exchange rate is 9.35 SEK per EUR, calculated as the average for years 2014 and 2015 according to Central Bank of Sweden (*Sveriges Riksbank*). The marginal values represent the change in hunting lease prices to an increase from zero to one additional home range (of lynx and wolf) or one additional individual (of bear). In column 1, we present the range of quantiles obtained with the UQR method for which the carnivore coefficients are statistically significant with 95% of confidence. Column 2 shows the marginal valuations per hectare of hunting ground in an effected municipality that correspond to the quantiles in column 1. Column 3 is the average value for the interval in column 2. Column 4 aggregates the marginal values per unit of carnivore territory or individual (i.e., it multiplies the impact per hunting ground in column 2 by the area suitable for hunting within an average municipality, that is 165 200 ha). And finally, column 5 is the average value for the interval in column 4.

of the country due to conflicts with livestock production and human-safety concerns. The wolf and brown bear management plans both target further dispersal southwards, and the wolf is expected to spread more rapidly due to a higher natural dispersal rate (EPA, 2014a, 2014b). There are no targets for the lynx distribution.

Information on snow depth and forest productivity was retrieved from the Swedish Meteorological and Hydrological Institute (SMHI) and The Swedish National Forest Inventory, respectively. The bear quotas for the year 2014 are documented in the website of the National Veterinary Institute (SVA). A bear quota is the maximum number of bears allowed by the authorities to be killed each hunting season, and it is determined based on predictive population growth models, population status and conservation goals. Considering that quotas are allocated at the county level and some counties are considerably larger than others, we control for the size of the counties in relation to the size of the hunting ground.

Income per capita, human population density, and distance from the hunting site to the nearest large city (here: Malmö, Gothenburg or Stockholm) are variables constructed on a municipality level and retrieved based on information in Statistics Sweden. Size of the hunting ground, number of hunting team members, income per capita, human population density and distance to the nearest biggest city were log-transformed to decrease high dispersion. Table 1 presents the descriptive statistics.

4. Results and discussion

4.1. Econometric implications

For the sake of comparison, we estimate OLS regressions to illustrate an average effect of carnivores on lease prices. Then, we proceed with CQR and UQR to show the heterogeneity of the impacts of carnivores on hunting lease prices notwithstanding that the magnitude and interpretation of the coefficients are different between the two quantile methods (McClean et al., 2013). Both are estimated using bootstrapped errors as in Borah and Basu (2013). Our baseline method is the UQR to facilitate the interpretation of the carnivore coefficients, and therefore to generalize these effects to the population quantiles. However, we also show the results of the CQR to compare the dispersion of lease prices within different conditional quantiles (Fournier and Koske, 2012), and to illustrate the disparity with the UQR estimates.

UQR coefficients suggest that large carnivores exert a negative and significant effect on hunting lease prices in the middle range of the overall distribution of hunting lease prices (Fig. 2). At the 5% level of significance, the coefficient of the wolf index is negative from the 48th to the 77th unconditional quantile, the coefficient of the lynx index is

negative from the 46th to the 77th, and that of the bear index is negative from the 34th to the 65th quantile. Carnivore indexes are not significantly different from zero in the lower parts of the distribution. The CQR and UQR estimations show that there exists heterogeneity in the impact of large carnivores when compared to the mean effect of the OLS estimations (Table 2). Moreover, wolf and lynx indexes in the 50th quantile of UQR are highly significant at 1% and near the magnitude of the OLS estimates. The bear index is not significant with OLS, but it is highly significant for the 50th quantile with UQR. Fig. 2 illustrates the plots per carnivore for the entire distribution, and Table 2 presents these results for the 10th, 40th, 50th, 60th and 90th quantiles.

The quantile plots in Fig. 2 illustrate that the confidence intervals of the carnivore coefficients become wider in the upper tail of the lease price distribution, particularly as of the 80th quantile.¹⁰ This is very likely due to the relatively small sample size in the carnivore data for this upper price segment (Sauro and Lewis, 2016). For the wolf index, only 24 non-zero observations out of 107 (i.e., where there is wolf presence) are within the 60th-100th quantiles. Similarly for the bear index, there are 34 non-zero observations above the 60th quantile (see Table A2 in the Appendix). This data limitation makes it difficult to identify carnivore effects in the upper-tail of the hunting lease price distribution. For comparison, observations with a non-zero lynx index are more equally distributed across the prices segments, and the lynx coefficient is significant at the 10% level in the 90th quantile of the UQR, see Table 2. This finding would still benefit from being replicated with a larger sample size.

We test the null hypothesis of equality of the UQR carnivore coefficient estimates obtained for different quantiles. For this purpose, we proceed as in Peeters et al. (2017). First, we obtain the full covariance matrix of the UQR coefficients after running a bootstrapped estimation of 500 replications. Then, we run a *Wald-F* test to determine if the UQR coefficient of the median quantile is statistically different from that of the 10th quantile (lower tail) on one hand, and that of the 90th quantile (upper tail) on the other hand. For the three carnivore indexes, our results reject the null hypothesis of the coefficients to be equal at the 10th quantile and the median, with 5% level of significance (Table A1, Appendix). This statistical difference across the unconditional quantile coefficients confirms the heterogeneous impact of carnivores particularly between the lower and middle range of the price distribution. However, we cannot reject the null hypothesis of equality between the

¹⁰ Non-significant results at the extremes are not unusual in hedonic studies applying the quantile regression framework (see Peeters et al., 2017, and Gamper-Rabindran and Timmins, 2013).

90th quantile and the median¹¹.

Other attributes also exhibit heterogeneous behavior across the hunting lease price distribution (Fig. A2 in the Appendix). The coefficient for the size of the hunting ground (variable log area) is more negative the higher the quantile, which implies that the impact of size is negatively stronger in the pricier grounds. A possible reason for this outcome is that in expensive areas, landowners with smaller hunting grounds demand higher payments possibly related to the potential damages produced by the hunting team. Forest productivity shows a highly significant impact in the middle range of the price distribution. Although forest productivity also lacks significance in the uppermost tail of the price distribution, the *Wald-F* test of pairwise equality does not yield statistical differences between the UQR coefficients in this segment and those in the middle range (Table A1, Appendix). Distance to the nearest big city is not significant in the OLS estimation, but the UQR method shows differential impacts on hunting leases close to the median, indicating that urban hunters exhibit a lower marginal valuation for hunting areas too far-off. Generally, fewer attributes are significant for very low-priced hunting grounds. One possible explanation for this outcome is that lease prices in this segment can be associated with substantial discounts for hunters who have a close relationship with the landowner and when the lease is associated with other exchange of services (e.g., related to hunting effort, or the management of land, buildings, or equipment).

To assess multicollinearity in the model, we study the correlation matrix and variance inflation factors (VIF) across covariates. The results, provided in Table A3, suggest that the three carnivore indices present a VIF lower than 2, and the correlation of each carnivore index with the other covariates never exceeds 52% (in absolute value). Thus, the key variables of interest are not highly collinear with each other or with the rest of covariates.¹²

The varying effects of large carnivores and other characteristics along the lease price distribution justify the use of the quantile regression framework as opposed to OLS. Moreover, the heterogeneous impacts of the CQR estimates exhibit very different patterns compared with the UQR coefficients (bold black lines Vs. blue lines in Figs. 2 and A2). Compared with CQR, the unconditional estimation applies to the overall distribution of the lease prices and the coefficient interpretation is relevant to the policy domain (Firpo et al., 2009; Borah & Basu, 2013).

4.2. Marginal implicit prices

We proceed to calculate the marginal implicit prices for the price segments in which carnivores have a statistically significant effect (i.e. mostly the middle range). Because we are interested in the marginal impact of carnivores along the whole distribution of lease prices, we only use the results from the UQR method to calculate the marginal values of each species. By taking Eq. (8), we could calculate the marginal implicit price of each carnivore for any population density index.

¹¹ For further insight on this *Wald-type F* test see Peeters et al. (2017) pp. 152.

¹² We also tried adding regional dummies to account for fixed effects in the three regions: Norrland, Svealand and Gotaland (base dummy). However, we did not include these as regressors in the final estimations, essentially because the carnivore distribution (i.e., the carnivore index regressors) describes and resembles this regional information. Namely, the wolf index is mostly non-zero when Svealand is equal to one, that is, 76% of the wolf observations are in Svealand. Similarly, the bear index is predominantly non-zero when Norrland is equal to one. Although Dalarna is a county that officially belongs to the Svealand region, it borders the Norrland region and hosts a fair amount of brown bears. The Norrland region together with Dalarna represent 64% of the bear (non-zero) observations. After including Svealand and Norrland in the main model, the dummies are non-significant, as well as the wolf and bear covariates. Moreover, the correlation between the Svealand dummy and the wolf index is 58%, and the correlation between the Norrland dummy and the bear index is 53%.

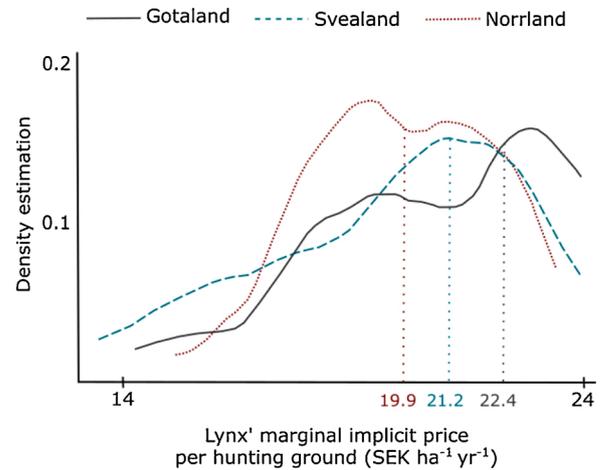


Fig. 4. Regional distribution of the lynx' marginal implicit prices per hunting ground, SEK per hectare and year.

Notes: This graph corresponds to the distribution of marginal implicit prices of lynx for the 290 municipalities divided by region. We take the 50th unconditional quantile to make the calculations for each municipality. The colored values in the graph relate to the distributional mean of each region.

However, a carnivore index unit is an ecological measure with limited economic interpretation. Therefore, we compute the marginal implicit prices in terms of carnivore territories (i.e. home ranges) and individual bears, instead of carnivore index units. Based on Eq. (8), the estimated marginal implicit price of an additional territory/individual of the *j* carnivore species for a given quantile is given by:

$$\frac{\partial P}{\partial B_j} \Big|_{\tau} = \left(\frac{\partial P}{\partial C_j} \Big|_{\tau} \right) \left(\frac{\partial C_j}{\partial B_j} \right) = \frac{\beta_{\tau}}{1 + C_j} \left(\frac{\partial C_j}{\partial B_j} \right), \quad (8)$$

where B_j is the number of territories (for wolf and lynx) or individuals (for bear). The term $\frac{\partial C_j}{\partial B_j}$ in Eq. (8) refers to the change in the carnivore index corresponding to one additional home range (for lynx and wolf) or individual (for bear).

In our sample, the average municipality area is 2 145 km² and the size of a lynx buffer zone is 320 km² (see data section); therefore, an increase in the lynx index corresponding to one additional home range (i.e. lynx buffer) is 0.1492 units (= 320 km² / 2 145 km²). Hence, $\frac{\partial C_j}{\partial B_j} = 0.1492$, for $j = lynx$. Following Eq. (8), the marginal implicit price for the τ th quantile of one additional lynx home range is $\frac{\partial P}{\partial B_j} \Big|_{\tau} = \frac{\beta_{\tau}}{1 + C_j} (0.1492)$. For instance, the marginal implicit price for the 50th quantile of one additional lynx home range is $\frac{\partial P}{\partial B_j} \Big|_{\tau=50} = \frac{-159.15}{1 + 0.1492} (0.1492) = -20.66$ SEK/ha and year. Similarly, the calculation for the 50th quantile of two additional lynx home ranges is $\frac{\partial P}{\partial B_j} \Big|_{\tau=50} = \frac{-159.15}{1 + 2(0.1492)} (0.1492) = -18.28$ SEK/ha and year, and so on. It can be noticed that the marginal values (in absolute terms) decrease as the number of buffer zones increase, see also Fig. 3(b).

In a similar fashion as with the lynx, an increase in the wolf index corresponding to one additional wolf home range (which sizes 1 000 km², see data section) is 0.4662 units (= 1 000 km² / 2 145 km²). Thus, the marginal implicit price for the τ th quantile of one additional wolf home range is $\frac{\partial P}{\partial B_j} \Big|_{\tau} = \frac{\beta_{\tau}}{1 + C_j} (0.4662)$, where $j = wolf$.

Because the brown bear index is measured in a different way

Table 4
Marginal implicit prices for lynx on a regional level, SEK per year.

Region	Average marginal implicit price (SEK ha ⁻¹ yr ⁻¹ in municipality of establishment)	Average marginal implicit price (million SEK yr ⁻¹ territory ⁻¹)
Gotaland	22.4	3.70
Svealand	21.2	3.50
Norrland	19.9	3.28

Notes: Exchange rate is 9.35 SEK per EUR, calculated as the average for years 2014 and 2015 according to Central Bank of Sweden (*Sveriges Riksbank*).

compared with the lynx and wolf, the procedure to calculate the term $\frac{\partial C_j}{\partial B_j}$ is different.¹³ The most recent estimation of the bear population in Sweden is 2 782 from 2013 (Swenson et al. 2017). Because the average municipality area of our sample (2 145 km²) corresponds to 0.526% of the total size of Sweden (407 340 km² excluding lakes), there are on average 14.65 bears per municipality (= 2 782 · 0.526%). Thus, an increase in the average bear index corresponding to one additional bear in a municipality is 0.0084 units (= 0.12/14.65; Table 1), hence, $\frac{\partial C_j}{\partial B_j} = 0.0084$. The marginal implicit price for the τ th quantile of one additional bear individual is thus $\left. \frac{\partial P}{\partial B_j} \right|_{\tau} = \frac{\beta_{\tau}}{1+C_j} (0.0084)$, where $j = bear$. Fig. 3 illustrates the marginal implicit price (expressed in absolute value) for the 50th and 60th unconditional quantiles as a function of carnivore territories/individuals, and compares this relationship with that obtained from OLS.

To provide one estimation of the economic cost of each carnivore species on hunting lease prices, we average the marginal implicit prices of the statistically significant unconditional quantiles (Table 3). In addition, we aggregate this result per carnivore territory (for wolf and lynx) and individual (for bear)¹⁴. Given that the marginal implicit prices vary with the number of buffer zones and bear individuals, it is important to clarify that we compute the marginal values of a change from zero to one home range, and from zero to one individual bear (as opposed to the change e.g. from one to two home ranges, or from four to five bears, etc). According to Table 3, the average marginal implicit price of a wolf territory is 20.3 SEK per hectare and year in the affected municipality. In proportional terms, this means that on average, an additional wolf home range reduces the mean hunting lease price by 21% in the municipality where it is established.¹⁵ The corresponding impact of an additional lynx family group, and an additional brown bear, is a decrease in the mean hunting lease price by 22.4% and 0.6%, respectively, in the municipality where the establishment occurs.

As a final exercise and given that the lynx is spread across the three regions in Sweden, we disaggregate the distribution of marginal implicit prices for lynx on a regional level¹⁶ (Fig. 4). To this end, we compute the marginal implicit price for each of the 290 municipalities at the 50th unconditional quantile (Table S1, Supplementary material). Based on these computations per municipality, we take the distributional mean of each region to calculate the associated marginal implicit price per lynx territory¹⁷ (Table 4). Besides the very high significance, the reason to

¹³ The brown bear index is based on individual bears while the wolf and lynx indexes are based on buffer zones (i.e. home ranges), see data section.

¹⁴ Because the average size of a municipality in this study is 214 500 hectares (i.e. 2 145 km²) and about 77% of the Swedish land territory is agricultural land or forest (Statistics Sweden), we assume that 165 200 ha (= 77% · 214 500 ha) on average are suitable for hunting in a municipality of our dataset.

¹⁵ Mean hunting lease price P=96.68 (Table 1).

¹⁶ Wolves are mainly present in the Svealand region and the Västra Götaland and Gävleborg counties. Brown bears are mostly in the Norrland region and the Dalarna and Värmland counties.

¹⁷ The 290 municipalities are distributed per region: 140 in Gotaland, 96 in Svealand and 54 in Norrland.



Fig. A1. Municipalities where the hunting areas of the study are located (painted in grey).

Notes: The study comprises 323 hunting grounds distributed across 154 municipalities (in grey) out of the total 290 municipalities in Sweden.

take the 50th quantile for our calculations is that the range of significant quantiles (column 1 in Table 3) are not statistically different from each other according to the *Wald-F* pairwise-equality test¹⁸.

The regional distribution of marginal implicit prices of the lynx species coincides to some extent with the regional distribution of hunting lease prices per region (cf. Fig. 1). Namely, the marginal implicit price of an additional lynx territory is the highest in the region with higher lease prices (Gotaland), and the lowest in the least expensive region (Norrland). Furthermore, Fig. A3 (Appendix) illustrates geographically the marginal implicit prices for the 290 municipalities in Sweden for all carnivore species.

5. Conclusion

This study contributes to the literature by studying market segmentation in the hunting sector, and the implications of such segmentation for the valuation of large carnivores. By using the unconditional quantile regression approach, we find differential effects of large carnivores on hunting lease prices when compared to the average impact obtained from ordinary least squares. These heterogeneous effects differ from

¹⁸ This implies that we could actually take any unconditional quantile from the 48th to the 77th to make the calculation of marginal implicit prices per municipality. Or analogously, this means that there is no statistical difference across the significant quantiles.

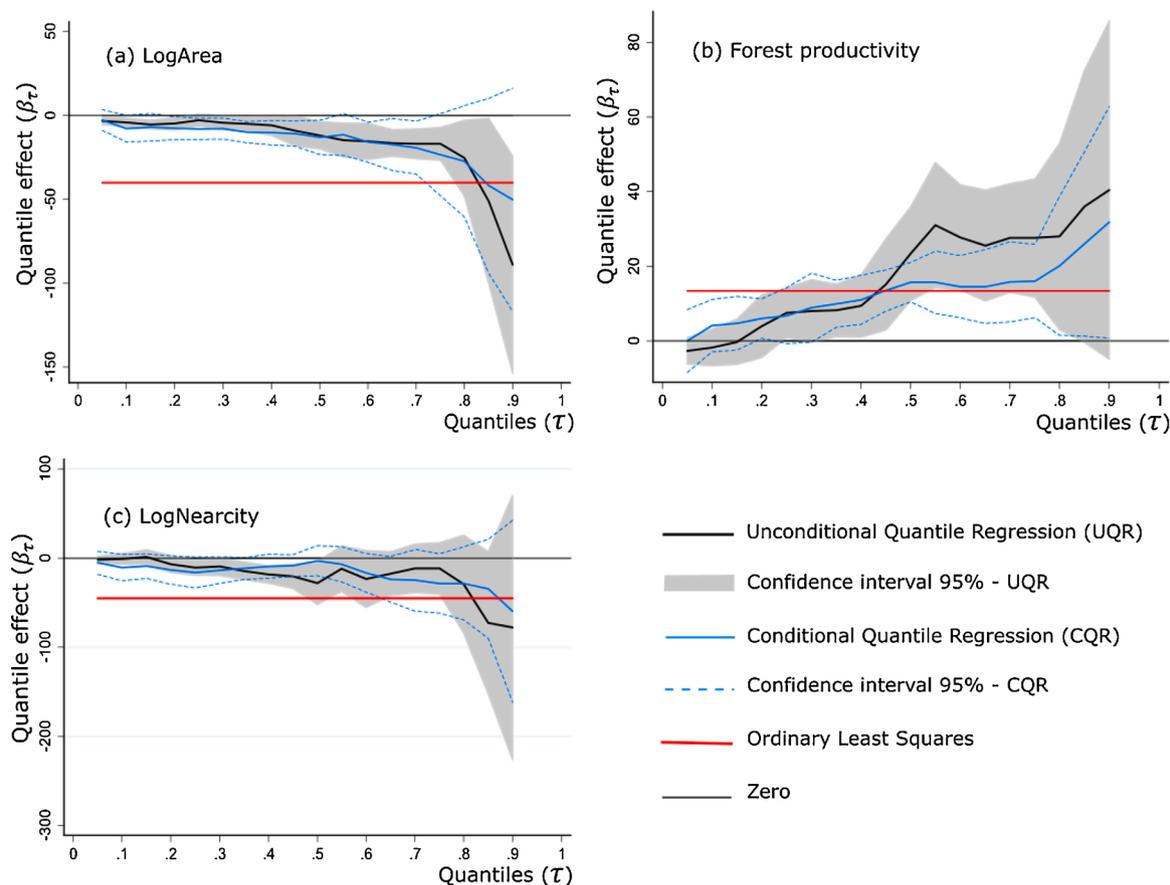


Fig. A2. Quantile plots for the estimated coefficients of other attributes with statistical differences across the price distribution: (a) Size of hunting area, (b) forest productivity, and (c) distance to the nearest large city.

those found with the conditional quantile method. According to our findings, large carnivores seemingly influence hunting lease prices negatively in the middle-range of the lease price distribution. Our results can be compared to Mensah et al. (2019) that takes 43 hunting plots in South Sweden and estimates that the average marginal implicit price of an additional lynx family group on hunting lease prices add up to EUR 162 thousand per year. Comparatively, our estimations make use of a much greater dataset, comprising 323 hunting grounds and covering a remarkably bigger portion of the Swedish territory, and yield a higher impact of EUR 379 thousand for the subset of the lease market where the impact is significant. This suggests that the impact of hunting values are unequally distributed across space.

Results indicate that the lower parts of the price distribution are plausibly unaffected by the presence of large carnivores. The lower price segment is generally insensitive to hunting plot attribute levels, potentially because the lease payments could be merely a symbolic financial transfer among relatives and friends, or associated with other transactions between the concerned parties. Also, the monetary transfers could be associated with informal agreements between land owner and hunters, e.g., on efforts to reduce game populations and hence browsing damage. Furthermore, it might be that hunters in this segment place a high value on having access to a hunting plot, independently of the attributes, e.g., due to the benefits if being part of the hunting community.

There are few observations with positive levels of wolf and brown bear in the upper price segments. This might explain the fact that impacts of the two species on hunting rental prices are not significant for this part of the price distribution. The lynx is geographically more spread across Sweden. Although this species does not appear to

influence the lower hunting rental prices, it has a significant effect at the 10% level in the upper part of the price distribution.

A limitation of our study is that we do not account for potential spatial spillovers on hunting lease prices provided that carnivore presence may influence hunting areas in neighboring municipalities. This spatial analysis could be developed in future research. Another limitation is the omission of landscape variables at the hunting plot level, which has been found by some authors to contribute to hunting-transaction prices (Shrestha and Alavalapati, 2004; Martinez-Jauregui et al., 2015). In addition, a noticeable caveat is the relatively few number of carnivore observations in the higher quantiles of the hunting lease price distribution. A larger sample size is needed to examine further the effects of carnivore presence in those upper price segments.

Our study was motivated by the need to identify conditions under which hunter-carnivore conflicts could be more pronounced. Results show the strongest impact on hunting lease prices in the mid-range of the price distribution. Given the considerable magnitude of the economic impact of additional wolf and lynx territories in the mid-range of the distribution, the incentives for poaching could be higher in these price segments. Poaching is argued to be a major cause of mortality for wolf in Sweden (Liberg et al., 2020), and recent studies suggest that a considerable share of Danish hunters could be willing to undertake illegal measures towards wolf (Højberg et al., 2017) while about one fifth of Swedish hunters abstain from reporting others' poaching (Peterson et al., 2019). Therefore, public resources for prevention and monitoring should be targeted towards price segments and locations where economic incentives and social acceptance for poaching are higher. Furthermore, our approach could be used to compare the

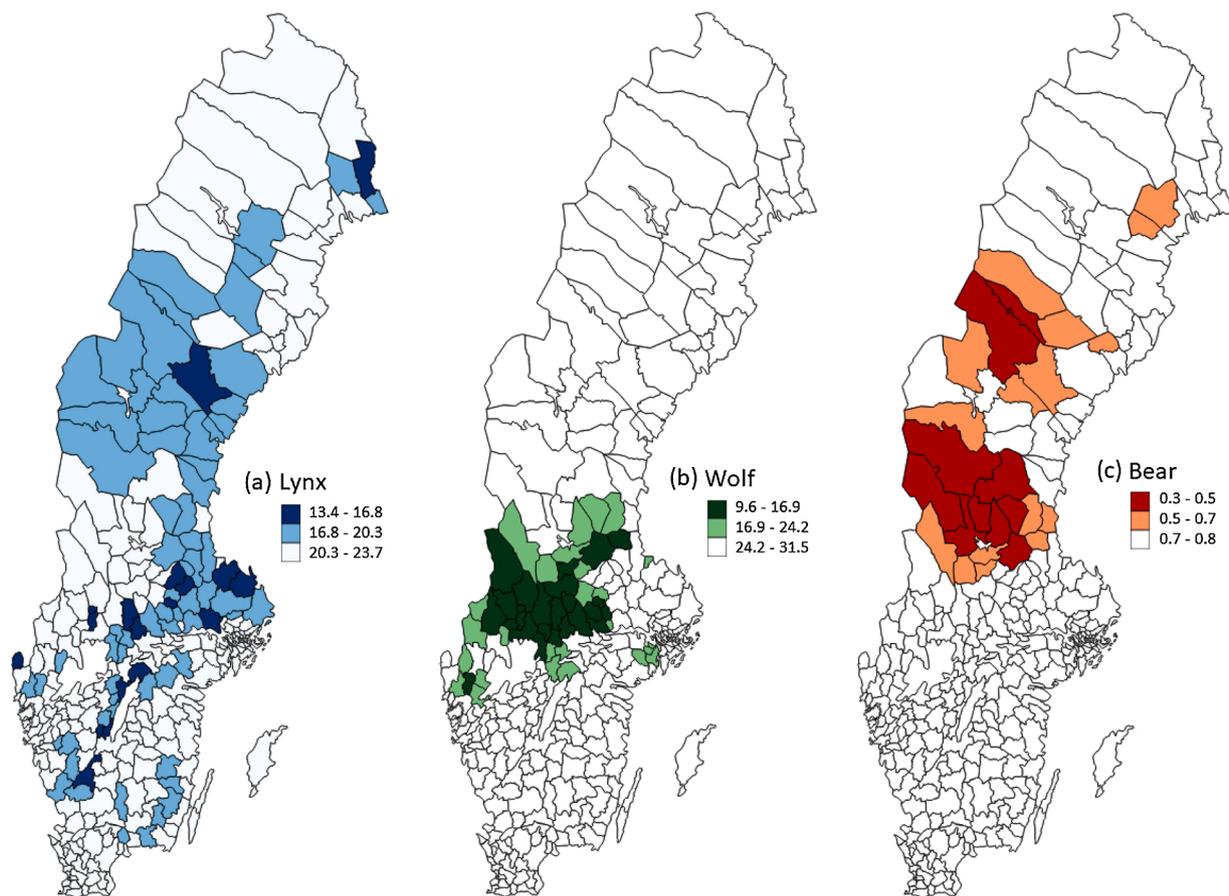


Fig. A3. Marginal implicit prices (SEK ha⁻¹ year⁻¹) per municipality for (a) lynx, (b) wolf and (c) bear.

Notes: The darkest municipalities have the lowest marginal implicit prices, which are those with the highest carnivore density. Each map is divided in three categories of equal-size intervals.

Table A1

Wald-F test for equality of UQR coefficients between the median quantile and the 10th/90th quantile.

UQR coefficient	50 th Vs. 10 th	50 th Vs. 90 th
<i>Large carnivores</i>		
<i>log(1+wolf)</i>	$z = 2.40^{**}$ $P\text{-value} = 0.016$	$z = -0.53$ $P\text{-value} = 0.594$
<i>log(1+lynx)</i>	$z = 3.5^{***}$ $P\text{-value} = 0.000$	$z = -0.76$ $P\text{-value} = 0.45$
<i>log(1+bear)</i>	$z = 2.60^{***}$ $P\text{-value} = 0.009$	$z = 1.07$ $P\text{-value} = 0.284$
<i>Other attributes</i>		
<i>log(area)</i>	$z = 1.83^*$ $P\text{-value} = 0.068$	$z = -1.94^*$ $P\text{-value} = 0.053$
<i>forest_prod</i>	$z = -3.77^{***}$ $P\text{-value} = 0.000$	$z = 0.61$ $P\text{-value} = 0.539$
<i>log(nearcity)</i>	$z = 2.40^{**}$ $P\text{-value} = 0.016$	$z = -0.55$ $P\text{-value} = 0.583$

Notes: The wolf index rejects the null hypothesis of pair-wise equality between the 10th quantile and the 50th quantile at the 5% level of significance, and both lynx and bear coefficients reject H0 with 1% level of significance. In contrast, none of the carnivore coefficients can reject the null hypothesis of pair-wise equality between the 90th quantile and the median quantile. Also, the table displays the other covariates for which there is statistical difference across unconditional quantiles. Size of hunting area exhibits heterogeneous effects among the 10th, 50th and 90th quantiles. The respective marginal effect of forest productivity and distance to the nearest large city is different between the 10th and the median, but such difference does not hold between the median and the 90th quantile.

marginal implicit price of additional carnivores across larger regions when evaluating zoning policies. In this respect we could only establish differences in costs across the three large Swedish regions for the lynx. Even then, the difference in marginal implicit price between regions is small, suggesting that increases in the lynx population would affect hunting lease prices in a similar manner in different parts of the country.

CRediT authorship contribution statement

Julian E. Lozano: Conceptualization, Methodology, Software, Formal analysis, Investigation, Writing - original draft, Visualization, Data curation, Writing - review & editing. Katarina Elofsson: Supervision, Writing - review & editing, Investigation, Funding acquisition, Formal analysis, Conceptualization. Yves Surry: Methodology, Formal analysis, Conceptualization.

Table A2

Number of carnivore observations within quantiles of the hunting lease price distribution.

Hunting lease price	Hunting lease price	Wolf index	Lynx index	Bear index
Quantiles	Number of (non-zero) observations			
0 th - 20 th	64	23	60	59
20 th - 40 th	64	32	58	58
40 th - 60 th	65	28	57	31
60 th - 80 th	65	8	45	15
80 th -100 th	65	16	38	19
Total	323	107	258	182

Table A3
Matrix of correlation and variance inflation factor.

	logarea	logmembers	forest_prod	snow_depth	log(1+wolf)	log(1+lynx)	log(1+bear)	bear_quota	log_popdens	log_incomepc	log_distance	forest_company
logarea	1.00											
logmembers	0.41	1.00										
forest_prod	-0.53	-0.24	1.00									
snow_depth	0.47	0.08	-0.81	1.00								
log(1+wolf)	0.10	0.26	-0.01	-0.07	1.00							
log(1+lynx)	0.21	0.17	-0.15	0.10	0.11	1.00						
log(1+bear)	0.40	0.21	-0.52	0.44	0.11	0.18	1.00					
bear_quota	0.39	0.19	-0.19	0.16	0.07	0.03	0.29	1.00				
log_popdens	-0.46	-0.11	0.61	-0.63	0.01	-0.25	-0.56	-0.19	1.00			
log_incomepc	0.07	0.05	-0.13	0.12	0.11	0.13	0.14	0.03	-0.56	1.00		
log_distance	0.52	0.16	-0.81	0.77	0.00	0.21	0.50	0.17	-0.71	0.21	1.00	
forest_company	0.18	0.01	-0.25	0.25	0.12	0.07	0.21	0.11	-0.35	0.21	0.30	1.00
VIF	1.93	1.37	4.32	3.71	1.16	1.12	1.78	1.23	4.44	1.90	4.03	1.18

Declaration of Competing Interest

The authors declare that there is no conflict of interest.

Acknowledgements

We thank Justice Tei Mensah and Ludo Peeters for their *unconditional* support, and the Swedish Environmental Protection Agency for the project's funding (grant # 802-0090-14).

Appendix A

Appendix B. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.landusepol.2020.105215>.

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