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EXTENDED MODEL OF THE NATURAL RESOURCE INPUT-OUTPUT MARKET: GAME MEAT IN LATVIA AS AN EXAMPLE

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Abstract
This paper incorporates input and output markets into a traditional natural resource economics model which was developed in fishery economics, in the context of terrestrial wild animal management. This model enables the division of the total game meat under the cull limit into personal consumption and market circulation. It is indicated that the utilization of game meat depends on the limitations in the optimum resource levels and the input market prices. While overuse is a typical problem in fishery economics, underuse is an issue in the case of wild animals, and the model successfully explains this issue.

JEL Classification: Q21, Q57
Keywords: game meat, input and output markets, oligopsony/oligopoly power model, underuse, personal consumption

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Introduction

Since ancient times, terrestrial wild animals (hereafter, wild animals) have been a source of essential material for manufacturing food, clothing, tools, etc. worldwide. Currently, wild animals are objects of commercial and sport hunting in the context of consumptive use. Their meat is considered healthier than livestock products and is used for traditional meals in numerous countries. Meat, fur, antlers, etc. of wild animals are highly demanded by certain countries, and the over-use of these wild animals is an important problem in resource management worldwide. The problem of over-use of wild animals has been primarily investigated using the natural resource economics model which was developed in fishery economics, and such studies began increasing in the 1990s.

As compared to other European countries, hunting is a relatively major activity in the Republic of Latvia; although the ratio of hunters to the total state population is slightly lower than that in the Scandinavian countries and in Germany, it is higher than the ratios in other European countries (Andersone, 2003, p. 13). The principal hunting species are the following four ungulates: elk (*Alces alces*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), and wild boar (*Sus scrofa*). The Latvian Hunting Regulation divides hunting species into limited and unlimited hunting species, and these four ungulates are classified as limited hunting species; their annual cull limits are determined by the Latvian State Forest Service (SFS), which is a branch of the Ministry of Agriculture (Andersone-Lilley and Ozolins, 2005, pp. 13-14).

However, the ratio of game meat production to total meat production is not high: game meat accounts for only a small percentage of the total meat in the market, and a major proportion of the game meat is personally consumed by hunters and their acquaintances (Kawata, Baumanis, and Ozolins, 2010, p. 901). This may also be true for the other European countries; the proportion of hunters among the total state population is at most 5% (Chardonnet *et al*., 2002), which suggests that in a number of countries, including Latvia, hunting and game meat is not used for industrial purposes but for amusement (sport hunting) and personal consumption. Therefore, traditional natural resource economics models, which were developed in fishery economics, where nearly all the landed fish is sold in the market, are often not appropriate for wild animals unless they are modified.

Therefore, the main purpose of this paper is to modify one of the traditional models, wherein hunters and meat-processing plants have not been clearly distinguished, by incorporating input and output markets in the context of wild animal management. As stated above, personal consumption may be ignored in the case of fisheries; however, it may comprise a substantial percentage of the total consumption in the case of wild animals. In order to consider personal consumption in the model, it is necessary to divide markets clearly into input and output and to divide producers into hunters and meat-processing plants. In order to make the content of this article more realistic, we will build a model with the Latvian case in mind. However, a few assumptions which do not necessarily reflect the real situation in Latvia have been adopted for the sake of simplicity.

In the traditional natural resource economics models, sole ownership is assumed and there is only one decision-maker (Gordon, 1954; Clark and Munro, 1975; Clark, 1990). In the case of Latvia, the population size of game species is estimated on the basis of scientific monitoring, and the annual cull limits are determined through discussions among the staff of the SFS, staff of the local offices of the SFS, which are situated at 10 different locations in the state, and representatives of the hunting clubs (mutual communication). Currently, there exists only one meat-processing plant in Latvia; however, the number of such plants may increase, as is subsequently discussed. Therefore, this paper assumes sole ownership in the supply side of the input market and extends the input and output market model, which enables the investigation of monopoly/monopsony and oligopoly/oligopsony.

There exists an established oligopsony-oligopoly model, with its variants, which have been used in other fields of economics. Existing research includes Azzam and Schroeter (1991), Chang and Tremblay (1991), Muth and Wohlgenant (1999), Weerahewa (2003), Vukina and Leegomonchai (2006), Fofana and Jaffray (2008), and Čechura and Šobrová (2008). As is subsequently discussed, when considering natural resources such as wild animals, an authority in charge of resource management must impose certain restrictions on oligopsony/oligopoly power, which may make it inappropriate to use the traditional oligopsony-oligopoly model.

2. Mathematical models

2.1. Outline of the settings

Assume that the game meat market may be divided into input and output markets. Hunters supply the carcasses of hunting species, and meat-processing plants demand these carcasses in the input market. These plants supply game meat, which is obtained from the carcasses, and the consumers demand this game meat in the latter market (Table 1).

Table 1. Summary description of subjects

Market	Input market		Output market	
	Supply side	Demand side	Supply side	Demand side
Subject(s)	The supply side is represented by a single institution, the Latvia State Forest Service (SFS).	Sole or multiple meat-processing plants	Sole or multiple meat-processing plants	Many consumers
Actions	The SFS sets the cull limit. Here, the SFS is assumed to be a sole owner, which is a representative of the supply-side subjects of the input market.	Meat-processing plants buy carcasses. Here, these plants behave as price takers as long as the factor price is between w^D and w^S.	Meat-processing plants sell meat. In our model, the amount of supply (game meat) is determined by the amount of carcasses. Meat-processing plants will maximize profit under this constraint.	Consumers buy meat.
Goals	The SFS – realization of a socially appropriate population level of hunting animal	Meat-processing plants – profit maximization under a given factor price	Meat-processing plants – profit maximization	Consumers – utility maximization, as characterized by the demand function
Information	The supply side of the input market does not know the realistic range of factor prices for the demand side.	The demand side of the input market does not have detailed information about the sole owner (TR_H and TC_H).		

First, let us examine the input market. There are two subjects in the input market: the supplier and the demander. We define the supplier as follows.

Definition 1

There are several subjects on the supply side of the input market, but let us suppose they behave as if they were the so-called sole owner, who decides the factor price in the input market in order to attain a socially appropriate population level and cull limit of hunting species[1]. In the real-life management of hunting, the SFS conducts an annual meeting every spring, where the SFS staff, staff of the local offices of the SFS, and representatives of hunting clubs (these subjects are hereinafter referred to as the supply-side subjects of the input market) discuss and determine the cull limits of hunting species on the basis of the estimated population size and other conditions. We suppose there is some range of appropriate population size (between $\underline{N}$ and $\overline{N}$) and a corresponding range of appropriate cull limit (between $\underline{H}$ and $\overline{H}$). Therefore, there is some corresponding range of factor prices (between $\underline{w}$ and $\overline{w}$).

Each of the 10 local areas has a number of hunting clubs, each consisting of numerous hunters. If there were no management, it would have been appropriate to assume that the supply side of the input market is in a perfectly competitive condition. However, hunting species in Latvia have long been under management control on the basis of decisions about population sizes and cull limits, which are made at the annual meeting. In existing research, sole ownership is often assumed in such a case, wherein there exists a representative of the supply-side subjects of the input market who makes decisions (Gordon, 1954; Clark and Munro, 1975; Clark, 1985, 1990). In our context, 'sole owner' refers to all supply-side subjects of the input market that reach an agreement on the population levels and cull limits for the year and behave as if they are one subject when it comes to decision making. Hereinafter, the two terms ('sole owner' and 'the supply-side subjects of the input market') are used interchangeably. We suppose the purpose of the sole owner to be as follows.

Assumption 1

The purpose of the sole owner in the input market is to attain a socially appropriate population level and corresponding cull limit of hunting species. We assume that the sole owner decides the range of the appropriate population size (between $\underline{N}$ and $\overline{N}$) and the corresponding range of the cull limit (between $\underline{H}$ and $\overline{H}$) on the basis of the information of population census, the disposition of local hunters, and other conditions. There is a range of appropriate factor prices (between $\underline{w}$ and $\overline{w}$) which

1. Usually, the sole owner is supposed to be the price taker. However, in this paper, we assume that the sole owner is the price maker.

correspond to the pair of an appropriate population level and corresponding cull limit. The sole owner selects one of the factor prices from this range and proposes it to the demand side of the input market[2]. We further suppose the following.

Assumption 2

Suppose information about the other side of the input market is limited. The sole owner does not have a realistic factor price for the meat-processing plant, and vice versa. Let us further suppose that these subjects will not cheat each other.

Assumption 3

Suppose the sole owner dominates the bargaining power, and the demand side of the input market behaves as a price taker: As long as the factor price, which the sole owner selects, is within a certain domain (that will be specified later), the demand side of the input market accepts this factor price. Otherwise, the sole owner selects another factor price from the range of factor prices for the demand side (between $\underline{w}$ and $\overline{w}$) and repeats the above procedure until an agreement is reached (this case will be referred to as case A). This procedure might fail if an acceptable factor price does not exist between $\underline{w}$ and $\overline{w}$. In this case, the meat-processing plant will refuse to buy carcasses (case B).

In the following account, hunting species will not be specified; however, it may be realistic to assume wild boar or red deer as examples.

All of the following situations will be realistic on the demand side of the input market: monopsony, oligopsony, or perfect competition. Until 2004, there were several meat-processing plants in Latvia (Kawata, 2006, p. 286); however, after it joined the European Union (EU) in 2004, there remained only one meat-processing plant. The number of meat-processing plants may increase in the future. This is because if potential plants satisfy the EU norm, they can enter/re-enter the meat-processing industry. This is also true for the meat-processing plants in other EU member countries.

If demand is lower than supply in the input market, the unsold game meat will be dumped. Currently, however, in the case of Latvia, hunters significantly prefer game meat, and that sold in the markets is usually the surplus of personal consumption. Therefore, the proportion of the game meat sold in the markets accounts for a small proportion of the total meat. Currently, certain people, including hunters, prefer game meat, and there is seldom an excessive supply of this meat. However, it would be appropriate to examine a case where there exists an excessive supply of game meat.

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2. Adding a dynamic bargaining element over w is quite simple. Based on Gibbons (1992), in Rubinstein's bargaining problem scheme, a dynamic bargaining solution will leave each player with an equal surplus under certain conditions. The author thanks one of the referees for pointing out this fact.

Subsequently, we investigate the output market. On the supply side of this market, it is possible to assume that one meat-processing plant and plants of other EU member states are as stated above. In addition, 5 to 6 plants deal with farmed deer meat; these plants provide substitutes for game meat. Therefore, the number of plants on the supply side of the output market is variable, and it may be realistic to assume monopoly, oligopoly, or perfect competition. The number of game meat consumers is large because both non-hunting consumers and hunting consumers whose annual catch of game meat is insufficient are compelled to purchase from the output market.

2.2. Supply side of the input market

2.2.1. Model selection

The supply side of the input market in this subsection and the demand side of the input market in the next subsection are described by the Gordon-Schaefer model, which is one of the most commonly used models in the field of natural resource economics (Gordon, 1954; Schaefer, 1957; Clark, 1990), where both dynamic and static analyses have been employed. Usually, a dynamic model is employed in the context of natural resource management; this model has been developed in order to compensate for the inadequacies of the static model in the first place.

However, in this paper, we develop a static model because it is sufficient and more realistic, for the following reasons. First, every spring, the sole owner estimates the population sizes of hunting species on the basis of the real hunts in the preceding year, vegetation conditions, severity of the previous winter, and conditions of predators; they determine the cull limits on the basis of this estimated population size. Therefore, it is more appropriate to use a static model rather than a dynamic model.

Moreover, as is established, the optimum population levels and the corresponding optimum hunt levels (cull limits) of a dynamic and a static model will coincide if the discount rate in the dynamic model is set at zero. The subjective discount rate of hunters may be regarded as zero, for the following reasons. First, hunters have been deeply committed to game species management (especially that of large carnivores) through data provision to researchers (Andersone, 2003, pp. 13–14), which may have enhanced understanding of the conservation of hunting species.

Second, because hunters regard game meat as extremely valuable and people are actively involved in hunting in Latvia, hunters have an incentive to use hunting species sustainably. Third, the main purpose of hunting is not for commercially treating game meat, but for personal consumption[3]. Therefore, for a majority of the

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3. An excessive supply of game meat does not mean overhunting by hunters. This is because hunters hunt on the basis of a cull limit. Therefore, excessive supply and the zero discount rate will hold simultaneously. We cannot deny the occurrence of poaching, but in our model, we ignore such a possibility, for the sake of simplicity.

hunters, it is sufficient to hunt hunting species only for their personal consumption, which may prevent overhunting. These facts imply that static analysis, which provides models that are simpler than those provided by dynamic analysis, is an adequate and more appropriate approach for this paper. Therefore, in the following subsection, we develop a static version of the Gordon-Schaefer model.

2.2.2. Static model

The Gordon-Schaefer model comprises the following surplus production model (Munro and Scott, 1985), wherein the growth in population is described by a logistic equation. Let r, K, N, and H denote growth rate, carrying capacity, population level, and real hunts, respectively. Then, the population dynamics are described by the following equation:

$$\frac{dN}{dt} = r\left[1 - \frac{N}{K}\right]N - H \tag{1}$$

where $H = qEN$, which is a special case of the Cobb-Douglas production function and E and q denote the hunting effort and the catchability coefficient respectively. In the Gordon-Schaefer model, some versions of total revenue (TR_H) and total cost (TC_H) of the sole owner are available. As a function of population size, net revenue $\Pi_H(N)$ of the sole owner is denoted as follows:

$$\Pi_H(N) = TR_H(N) - TC_H(N) = w\left[1 - \frac{N}{K}\right]N - \frac{ar}{g}\left[1 - \frac{N}{K}\right] \tag{2}$$

where w and a denote the factor price in the input market and the unit cost of hunting effort respectively. Further, let TC_H : TC_H alternatively denote the function of the hunting effort; E : $TC_H(\mathrm{E}) = \alpha E$. Assuming that c is denoted as the unit cost of harvesting yields

$$\frac{TC_H(E)}{H} = c(N) = \frac{a}{qN} \tag{3}$$

Using $H = qEN$, eq. (3) is modified as follows:

$$TC_H\left(H^S, N^S\right) = \frac{a}{qN^S} H^S \tag{4}$$

where N^S and H^S imply the sustainable population level and the corresponding sustainable hunt level (cull limit) respectively. These pairs - sustainable population level and the corresponding sustainable hunt level - exist infinitely. A graphical description of this case is presented in Prato (1998, p. 165). Eq. (4) holds only if the pairs of N^S and the corresponding H^S are used, where N^S and the corresponding H^S satisfy the following relationship:

$$H^S = r\left[1-\frac{N^S}{K}\right]N^S \tag{5}$$

From eqs. (4) and (5), it follows that

$$TC_H(N) = \frac{ar}{q}\left[1-\frac{N}{K}\right] \tag{6}$$

From the first order condition of eq. (2), it follows that

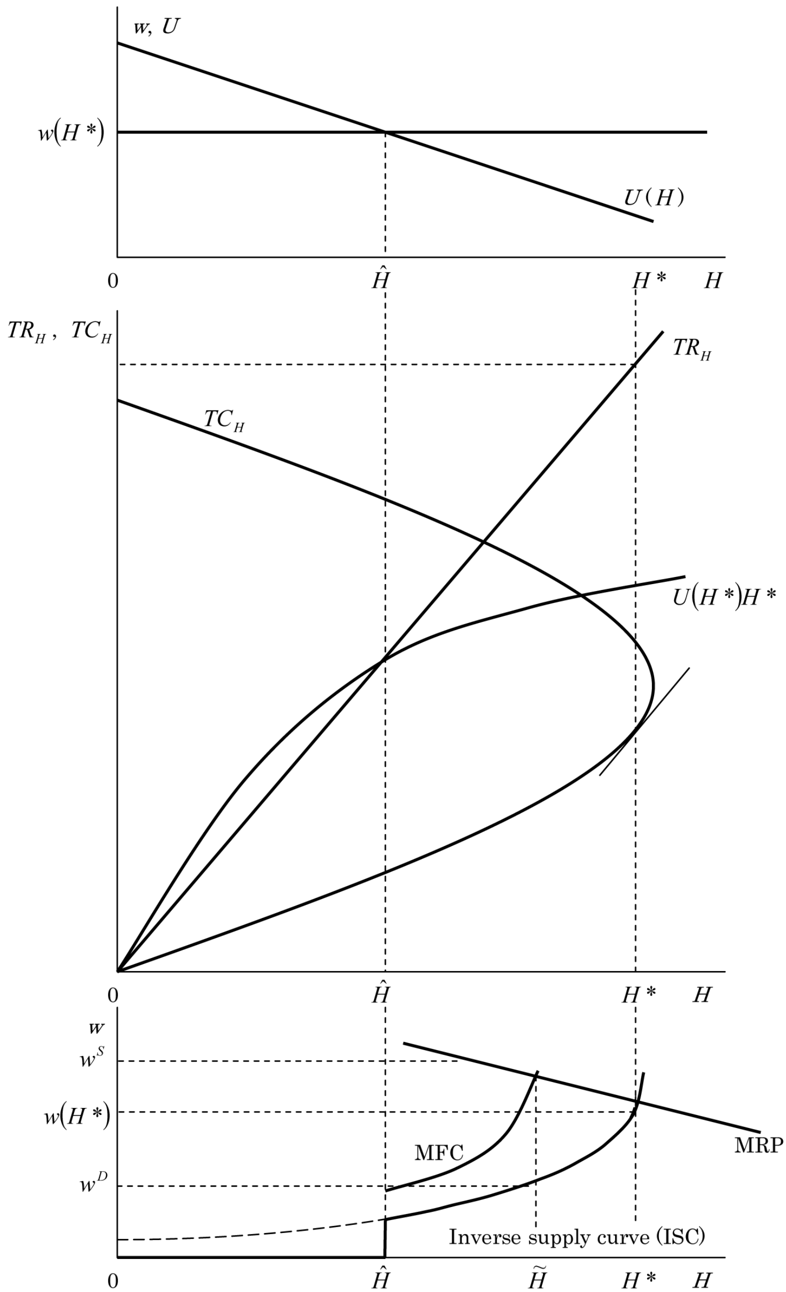
$$N^S = \frac{K}{2} + \frac{a}{2wq} \tag{7}$$

Inserting eq. (7) into eq. (5) yields H^S. If the certain set of N^S, H^S, and w is accepted by both the supply and demand sides of the input market, these pairs are hereinafter denoted as N^*, H^*, and $w(H^*)$, respectively.

Subsequently, H^* is divided into personal consumption and market circulation (provision to meat-processing plants). Hunters are assumed to receive substantially high utility from the consumption of game meat. Let $U(H)$ denote the marginal utility of game meat in monetary terms. If $\hat{H}$ denotes the hunting level when $w = U(H)$, then personal consumption and market circulation will be denoted as $\hat{H}$ and $H^* - \hat{H}$ respectively (Figure 1). As is subsequently stated, the amount of game meat denoted by $H^* - \hat{H}$ will not be necessarily supplied to the market. Under the current markets in Latvia, the amount of game meat may be regarded as $\hat{H} < H^*$, which implies that the game meat provision to the market exists.

In the charts in Figure 1, the value of w is fixed at the constant $w(H^*)$. Since a meat-processing plant has no information regarding the *TC* curve, which is derived with w being a function of H, the meat-processing plant is assumed to negotiate prices on the basis of the *MC* and the marginal factor cost (MFC) curves, which are derived from the TC_H (total cost curve when $w = w(H^*)$). As usual, the MFC curve is located above the *MC* curve in this paper (proof is provided in Appendix A).

Figure 1. Game meat market model



2.3. Demand side of the input market

Subsequently, we derive an inverse supply function of the meat-processing plant. Hereinafter, we assume that there is only one meat-processing plant; this assumption can be relaxed, if necessary. Eq. (4) is described with the help of a figure (see for example, Prato, p. 165). To derive the inverse supply function, it is easier to replace horizontal axis (H^*) and vertical axis (TC_H) when differentiating TC_H with respect to H at $N = N^*$ and $H = H^*$. Therefore, let us assume the following change in the axis: let H^* represent the vertical axis and TC_H represent the horizontal axis. Then, this figure will be a convex upward quadratic function that crosses the origin and its mathematical equation as follows (Kawata, 2008):

$$H^* = -\alpha TC_H^2 + \beta TC_H \tag{8}$$

where α and β are constants. Differentiating eq. (8) with respect to TC_H, calculating the inverse function, and subsequently substituting the result into eq. (4) yields

$$\left.\frac{dTC_H}{dH}\right|_{N=N^*,H=H^*} = \frac{qN^*}{-2\alpha aH^* + \beta qN^*} \tag{9}$$

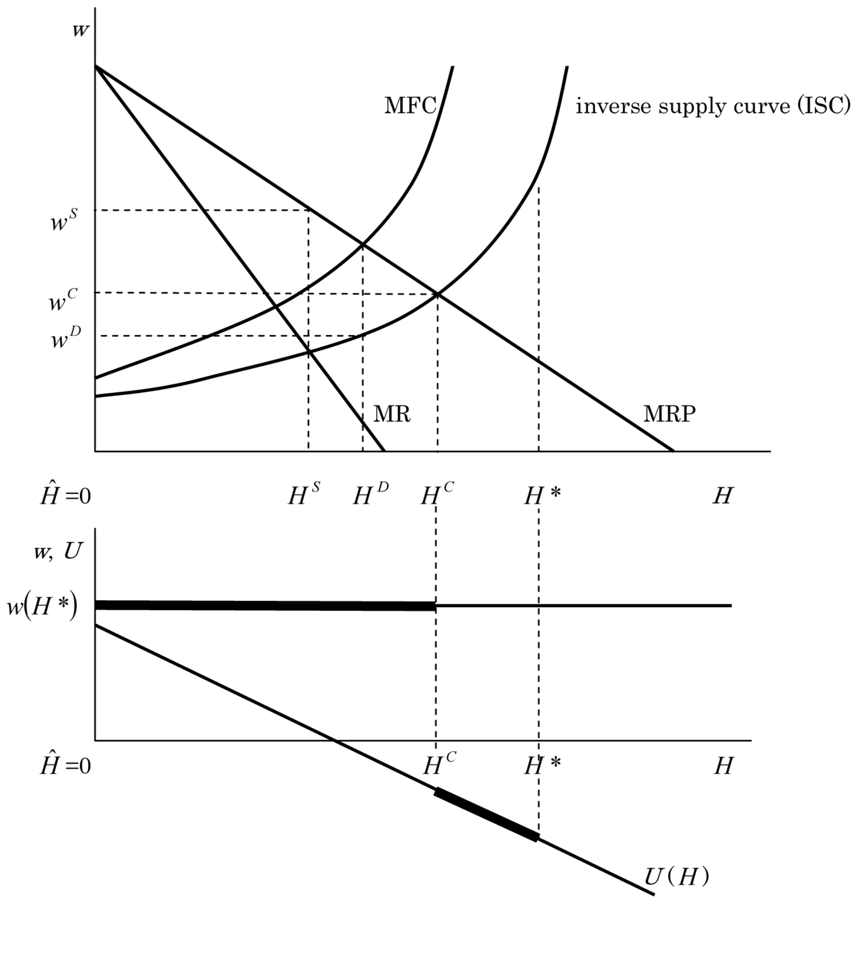
This equation is the inverse supply function (ISF) of a meat-processing plant (lower chart of Figure 1). The ISF described in Figure 1 is derived from TC_H, where $w = w(H^*)$. Note that once the value of w changes, N^* and the corresponding H^* will also change, and as a result, the ISF will shift. However, it is less realistic to assume that a meat-processing plant has such detailed information on the pairs of N^* and H^*. Therefore, a meat-processing plant is assumed to make decisions on the basis of the ISF, which is derived from TC, where w is fixed at $w(H^*)$ (Table 1). Here, we examine two cases as suggested in Assumption 3.

<u>Case A: When there is no restriction on N^*, H^*, or both in terms of game management</u>

Let w^S, w^D, and w^C denote monopoly price, monopsony price, and the price that corresponds to the point of intersection between the marginal revenue product (MRP) and the inverse supply curve (ISC) in the input market respectively. The term w^C corresponds to the price under perfect competition, where social welfare (or surplus) is maximized. In addition, let H^S, H^D, and H^C denote the corresponding demand/supply of w^S, w^D, and w^C, respectively (Figure 2). On the basis of Weerahewa (2003), the cull limit between H^S and H^C (which corresponds to the price between w^S and w^C) and that between H^D and H^C (price between w^C and w^D) is obtained when oligopoly and oligopsony exist respectively.

Under a bilateral monopoly case, it is an established fact that the market price will be between w^D and w^S and that the level of this market price depends on the negotiation between the supply and the demand sides. Let us suppose that a meat-processing plant will treat game meat if its price is between w^D and w^S (Table 1). If the range of sustainable population levels includes the population level that corresponds to w^C, this factor price would be the most suitable, and there would be no reason to select prices higher than w^C. The above information indicates that under the social objective of game animal management, the market price is determined such that it falls between w^C and w^D, and H^* will be determined so that $w(H^*)$ satisfies $w^C \leq w(H^*) \leq w^D$. As a result, demand/supply will be $H^D \leq H^* \leq H^C$.

Figure 2. Establishing the cull limits for personal consumption and market circulation



Case B: When there is a restriction on N^*, H^*, or both in terms of game management

However, whether case A can be established is not guaranteed. $H^D \le H^* \le H^C$ will not be realized for certain positions of the MRP curve. This occurs when there is a limitation on N^* (or H^*). There will be cases when the authority needs to induce the level of N^* in order to cope with the ecological relationship between the targeted hunting species and other ungulates, large carnivores, or both. One of the following three cases may occur:

(1) $H^* < \hat{H}$

In this case, the entire quantity of game meat is personally consumed.

(2) $\hat{H} \le H^* < H^D$

Note that in this case, the price is below w^D. Since a meat-processing plant will not purchase any game meat, there is no provision in the market. If $U(H^*) > 0$, the entire quantity of game meat is personally consumed. If $U(H^*) \le 0$, the cull limit will not be satisfied. If H^0 is assumed to satisfy $U(H) = 0$, then personal consumption will be less than the cull limit by $H^* - H^0$.

(3) $H^C < H^*$

If $U(H) > 0$, then the entire quantity of game meat between H^C and H^* is personally consumed. If $U(H) \le 0$, then there is no hunting and the cull limit will not be satisfied by $H^* - H^0$, where $H^0 \ge H^C$ (lower chart of Figure 2).

3. Analyses and discussions

3.1. Restrictions on using game meat and analyses of underuse issues

Traditional game management usually focuses on biological aspects; it only partially considers the economic aspects. Therefore, when authorities determine the optimum N^* and H^*, the conditions for the feasibility of game meat markets are usually not considered, and the consumption of game meat is simply regarded as the utilization of the resources obtained by sports hunting. However, the present model clearly demonstrates that when game meat is treated in the market, there will be a few constraints in the process of deciding the optimum N^* and H^*. This result possesses the following two unique aspects: First, this result clearly suggests that the economic perspective is also crucial and must be incorporated in game animal management. Second, this result emphasizes that there will be a few constraints in determining the optimum N^* and H^*, which have been ambiguous in the traditional natural resource economics models.

Since the model in this paper is a static model and TC is nonnegative, N^* must always greater than N^{MSY}, which is the population size that realizes the maximum sustainable yield (MSY). Therefore, if N^* increases, the corresponding H^* will always decrease. The lower the MRP curve, the lower the value of H^C (the more left-handed the position of H^C). It follows that in order to realize the condition H^* < H^C, it is necessary to establish a higher value of N^* and a lower value of the corresponding H^*.

MRP is the marginal revenue when a meat-processing plant sells game meat. As is intuitively true, as the demand for game meat increases, the position of the MRP curve becomes higher and H^C increases (the more right-handed position of H^C). As the demand for game meat decreases, it is more difficult to satisfy the condition H^* < H^C.

If $H^C < H^*$, game meat is personally consumed between H^C and H^*. In that case, if $U(H) < 0$, then the cull limit will not be satisfied by the amount of $H^* - H^0$. This description clearly explains the underuse issues which have been encountered by a few countries for certain hunting species. Traditional natural resource economics models could not clearly explain such issues; the ability to elucidate this issue is also one of the unique features of the model in this paper.

For example, beavers are currently underused in Latvia. However, they were exterminated in the 19th century, and the restocking and recovery of beavers began in 1927 and around the late 1950s respectively. Consequently, the number of beavers increased and hunting restarted in 1981. Until 1991, Latvia could sell fur to the Soviet markets, and, therefore, the annual cull limits were satisfied every year. However, the cull limits have not been reached since 1991 for the following reasons: (1) When Latvia regained its sovereignty from the Soviet Union, it lost the Soviet fur markets; (2) the demand for beaver meat is rather low; and (3) there exist hunting species that are more attractive (Balodis, 1990; Kawata, Baumanis, and Ozolins, 2011). In other words, after 1991, since $w(H^*) = 0$ and $H^* < H^0$, cull limits have not been satisfied by the amount of $H^* - H^0$.

3.2. The monopsony equilibrium and the reasons for divergence from this equilibrium

If the demand side is monopsony and the supply side is perfect competition, then the market price will be w^D, whereas if the supply side is monopoly and the demand side is perfect competition, then the market price will be w^S (Figure 2). In the case of a bilateral monopoly, the price will be between w^D and w^S and will be determined on the basis of the negotiation between the supply and demand sides. The prices determined at w^C coincide with the price under perfect competition of both the supply and the demand sides. According to Weerahewa (2003), under oligopsony, the market price will be between w^D and w^C, whereas under oligopoly, the market price will be between w^C and w^S. In the light of the above information, the real market price differs from w^D in the following cases: (1) a bilateral monopoly case, where the negotiating power of the demand side is so strong that the demand side can select w^D, and (2) an oligopsony case.

The present model has been developed as a bilateral monopoly model in the input market, where the supply side of the input market includes the authority and the market price is determined between w^C and w^D. This paper may provide another possible reason why the market price differs from w^D and will be between w^C and w^D. Since some meat-processing plants which could not satisfy the EU norm have closed down, there is currently only one meat-processing plant in Latvia (Kawata, 2006). Therefore, the current situation in Latvia is a monopsony and market price can be w^D. However, the market price may not be w^D because the present model deals with natural resources, consequently, different factors are introduced as compared to the usual bilateral monopoly. If there is no game animal management, then the supply side comprises numerous hunters who may behave as price takers. As a result, w^D will be realized.

However, when game animal management is implemented, the situation may be regarded as a kind of a bilateral monopoly case. This is because the supply-side subjects may be regarded as sole owners when determining N^*, H^*, and $w(H^*)$. This case may be classified as a variance of the traditional case (1). However, this is the case where the supply and the demand sides negotiate in order to fulfil their respective objectives (the realization of socially optimum game animal management and the maximization of net revenue), and it may be more appropriate to consider this as a third case.

There is another implication. Meat-processing plants were assumed to treat carcasses if their prices are between w^D and w^S. However, if these plants do not accept $w(H^*)$, game meat will not be supplied to the market. As a result, the cull limit will not be satisfied and underuse will become an issue.

3.3. Implications of the assumptions

In this paper, $w(H^*)$ was assumed to be determined on the basis of the negotiation between the demand and the supply sides of the input market. Further, we assumed that once $w(H^*)$ is determined, meat-processing plants will consider $w(H^*)$ as a constant and use the *TC* and other curves, which are derived under this $w(H^*)$. However, as stated above, if the value of H^* changes, the value of $w(H^*)$ will also change. We assumed that meat-processing plants do not possess detailed information. There are two reasons for this simplification: first, to reflect the fact that meat-processing plant(s) must not possess detailed information in the model; second, without this simplification, the model cannot be solved analytically and will require numerical simulation.

Obtaining N^* and H^* assumes the first priority. As a result, optimization will not be possible in the traditional oligopsony/oligopoly power model. Usually, this model assumes that $kQ = H$ ($kq_i = h_i$) and the optimum solution Q^* is derived from the first-order condition. However, in the present model, H^* is determined in the context of game animal management, and once H^* is determined, Q^* is also automatically determined (see Appendix B). This implies that the present model clearly indicates that in the context of game animal management, meat-processing plants cannot necessarily obtain a monopolistic optimum solution. However, Q^* may coincide with the optimum solution of meat-processing plants; the corresponding H^* lies within the feasible range of H^* from the perspective of game animal management, and the negotiation power of meat-processing plant(s) is sufficiently strong to select this H^*.

This indirectly implies that in the context of game animal management, if the utilization of game meat in the market is considered, then the economic entities in the input market are subject to special conditions. The authority must intervene in the game meat market in order to attain a socially optimum population level and corresponding real hunts.

4. Conclusions

The number of academic papers that consider hunting species and employ slightly modified versions of the natural resource economics models which were originally developed in fishery economics has increased significantly since the 1990s. The premise of such natural resource economics models is that approximately all the game meat is sold in the markets. However, in the case of hunting species, the rate of personal consumption is relatively high, and it is often inappropriate to employ traditional models. This paper, therefore, modified one of the traditional natural resource economics models by distinguishing the supply and demand sides in the input and output markets and developed a modified model in the context of game animal management.

The following are suggested on the basis of the model employed in the paper: First, if game meat is utilized throughout the market, then there will be a few constraints while determining the optimum N^* and the corresponding H^*. Second, in the context of game animal management, when the social goal of obtaining an optimum N^* and corresponding H^* heavily reflects the market price, the market price differs from the monopsony price. Third, in the context of game animal management, the oligopsony/oligopoly power of private companies must be restricted to a certain extent. As a result, the application of the usual oligopsony/oligopoly power model is not appropriate.

The model in this paper makes the following other contributions: Underuse will be a problem for certain pairs of N^* and H^* in case A discussed in the aforementioned paragraph. In case B, if meat-processing plants do not agree with the input market price, then underuse may occur. Traditional models primarily focus on overuse issues. The present model succeeded in explaining underuse issues by incorporating the input and output markets and corresponding economic entities.

Finally, the recommendations based on this paper are summarized as follows. First, traditional natural resource economics models cannot treat self-consumption and underuse issues; therefore, the use of extended models is recommended. Second, when underuse issues occur, the real market cannot deal with them. From the perspective of ecology, there are appropriate population sizes which are difficult to attain because of economic constraints. Therefore, governmental intervention in the carcass/game meat markets is recommended.

Appendix A

From eqs. (9) and (11), the following equation is provided under monopsony:

$$\Pi = TR_{Qi}(Q) - \frac{qN^* H^*}{-2\alpha a H^* + \beta q N^*}. \tag{A1}$$

One of the first order conditions is $\frac{\partial \Pi}{\partial H^*} = 0$, which yields the following equation:

$$\{TR_{Qi}(Q)\}' = \frac{\beta [qN^*]^2}{[\beta q N^* - 2\alpha a H^*]^2}. \tag{A2}$$

Here, $\{TR_{Qi}(Q)\}' = \frac{\partial TR_{Qi}(Q)}{\partial Q} \frac{\partial Q}{\partial H^*}$ and the RHS of eq. (A2) is the marginal factor cost (MFC).

Next, the locations of the MFC and of the inverse supply curve are compared. Taking the difference between eq. (A2) and eq. (9) yields the following result:

$$\frac{qN^* 2\alpha a H^*}{[\beta q N^* - 2\alpha a H^*]} > 0. \tag{A3}$$

Since eq. (A3) is positive, it is indicated that the MFC curve is located above the inverse supply curve.

Appendix B

The production function of the meat-processing plant i is assumed to be $q_i = F(h_i)$. Further, it is assumed that $Q = \sum_{i=1}^{M} q_i$ and $H = \sum_{i=1}^{M} h_i$. Let $p = p(Q)$ denote the inverse demand function; then, the total revenue of the meat-processing plant i, ($TR_{Qi}(Q)$), is given by

$$TR_{Qi}(Q) = p(Q)q_i. \tag{B1}$$

Next, the total cost of the meat-processing plant i, ($TC_{Qi}(Q)$), is derived. Since the inverse supply function $w(H^*)$ is provided as eq. (9), $TC_{Qi}(Q)$ is given by

$$TC_{Qi}(Q) = w(H^*)h_i.$$

It follows that the net revenue of the meat-processing plant i is given by

$$\Pi_{Qi}(Q) = TR_{Qi}(Q) - TC_{Qi}(H) - OC_i = p(Q)q_i - w(H^*)h_i - OC_i. \tag{B2}$$

Here, OC_i denotes other costs and is constant (Čechura and Šobrová, 2008). k is denoted as an input-output coefficient, and it is assumed that $kQ = H$ (also, $kq_i = h_i$). In a usual market, the meat-processing plant i may select q_i, which maximizes the value of eq. (B2). However, in the context of game animal management, since H^* is given, q_i is determined in proportion to the value of k.

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