Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices?[1]

Marius Warg Næss[1,*] & **Bård-Jørgen Bårdsen**[2]

[1] Norwegian Institute for Cultural Heritage Research (NIKU), High North Department, Fram Centre, N-9296 Tromsø, Norway.

[2] Norwegian Institute for Nature Research (NINA), Arctic Ecology Department, Fram Centre, N-9296 Tromsø, Norway.

Corresponding author:

Marius Warg Næss, e-mail: mwnass@outlook.com; marius.naess@niku.no

Abstract: A growing body of evidence shows that, for nomadic pastoralists, herd accumulation is an efficient strategy for buffering environmental variation and maximizes long-term survival. Pastoralists may thus view livestock as investments, or 'banks on the hoof', that works as insurance against unpredictable environmental conditions. This highlights a different logic than strict market logic where producers are expected to follow the 'law of supply', i.e. that when the price of a product rises suppliers should be willing to offer more of the product for sale. In terms of insurance, increased meat prices may make it possible for pastoralists to slaughter fewer animals for the same financial gain as when prices are low and subsequently convert unslaughtered animals to herd capital. This study

[1] This is the accepted version of the paper and as such may differ from the final corrected proof which can be accessed at http://dx.doi.org/10.1007/s10745-015-9758-9.

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.
investigated to what degree Saami reindeer herders follow a market or risk logic by investigating how slaughter strategies have been shaped by increasing meat prices. While slaughter strategies vary regionally in the reindeer husbandry, the results from this study indicate that pastoralists follow a logic shaped neither by risk nor market considerations alone, but rather a combination. Pertinently, results from this study support the general hypothesis that pastoral slaughter strategies entail balancing the risk beneficial aspects of increasing herd size against economic gain through meat sales. This should have important management implications since current management schemes aiming to reduce the number of reindeer by stimulating slaughter through economic subsidies is based on the assumption that herders are meat producers motivated by monetary gains alone.

Keywords: Risk management; reindeer husbandry; nomadic pastoralism; Norway.

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

INTRODUCTION

Herskovits (1926) showed that cattle were a dominant element among East African pastoralists. Cattle were important in many ways, e.g. as a symbol of wealth, dowry, and in ceremonies. As such, pastoralists' preoccupation with having large herds has been explained as having little or nothing to do with economic considerations. Subsequently, the term the "East African cattle complex" was coined to point to the social value of cattle, often without reference to the consumption requirements of households. Nomadic pastoralists were thus viewed as non-rational, having an economically unreasonable attachment to livestock (Lamprey 1983). Moreover, it has also been argued that pastoralists build large herds in order to transfer them in bridewealth (McCabe 2004), increase reproductive success (Mace 1996) and to show off through conspicuous display (e.g. Paine 2009).

A growing body of evidence shows that herd accumulation is an efficient strategy for buffering environmental variation (e.g. Næss and Bårdsen 2010, Næss and Bårdsen 2013, McPeak 2005, Templer *et al.* 1993, Fratkin and Roth 1990). Among Saami reindeer herders in Norway it has been shown that herders with large herds have comparable larger herds from one year to the next (Næss and Bårdsen 2010) as well as before and after crisis periods[2] (Næss and Bårdsen 2013). In short, herd accumulation maximizes long-term survival for pastoralists (see also Mace and Houston 1989). Herd accumulation has thus a clear

[2] Environmental hazards, such as drought, floods and icing significantly affect livestock survival and reproduction (cf. Næss 2013, Næss and Bårdsen 2013 for examples). Icing events and too much snow during winter resulting in mass starvation have been reported to dramatically reduce reindeer populations: In 1918 one reindeer population was, for example, reduced by a third (Bjørklund 1990:79), and substantial reductions have been reported for 1958, 1962 and 1968 (Hausner *et al.* 2011:6). More recently, winters of 1997 and 2000 have been described as catastrophic and resulted in severe loss (Hausner *et al.* 2011:6).

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.
economic rationale and cannot be viewed solely as the result of non-economic values such as prestige and status (Næss and Bårdsen 2010, McPeak 2005). The risk beneficial aspect of herd accumulation thus provides the rationale for why both reindeer herders (Næss *et al.* 2010, Næss *et al.* 2009) and pastoralists in general (Næss 2012) invest labour in order to increase herd size.

The overstocking debate

In Norway there has been a recent increase in reindeer abundance: the number of reindeer peaked in the early 1990s, decreased until 2000/2001, and thereafter increased and reached a historical high level in 2010 (Næss and Bårdsen 2013: fig. 1). Specifically, in Finnmark, which contains **>**70**%** of Norway's Saami reindeer herders, reindeer abundance increased by ~40% from 2002 to 2010 (OAGN 2012), and this has created a public debate pertaining to overstocking and unsustainable pasture use.

The Office of the Auditor General of Norway, in its investigation of the sustainability of the reindeer husbandry, suggested that a large part of the pastures in Finnmark is overused: in 2009 >50% of the lichen cover was overgrazed and ~40% was reduced (OAGN 2012). For 90% of the areas still covered by lichens, the thickness of the cover was below the threshold for when the lichen is at its most productive (OAGN 2012). In the early 2013, news reports stated that 12 summer districts in Finnmark had been instructed to reduce the number of reindeer by ~30-50% (Somby 2013). Moreover, a unified Norwegian Parliament supported *enforced* slaughter to reduce the number of reindeer (Larsson and Ballovara 2013). While the Norwegian Ministry of Agriculture and Food (MAF) wanted a reduction of

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.
>40%, the Reindeer Husbandry Board agreed early in 2013 upon a 5% reduction by the end of 2013 and further reductions in 2014 and 2015 if necessary (Larsson and Ballovara 2013).

In Norway then there is a debate pertaining to the sustainability of the reindeer husbandry. From a political point of view, the primary objective of management policies is to achieve *ecological*, *economic* and *cultural* sustainability (Ulvevadet 2012) where ecological sustainability is emphasised as both economic and cultural sustainability is assumed to depend on ecological sustainability (Ulvevadet 2012). While ecological sustainability is somewhat loosely conceptualised, in practice policies are concerned with one thing, i.e. *reducing the number of reindeer*.

Two tools are used to achieve this goal: (1) several economic incentives and subsidies aiming to stimulate reindeer herders to increase slaughter (Anonymous 2008a:51, see Ulvevadet and Hausner 2011 for details about the subsidy system). (2) Redistributing semi-common winter pastures to smaller managerial units as clear area designations are assumed to be important for determining the highest number of reindeer that herders' can keep and still be ecological sustainable (Anonymous 2005a:19).

Misrepresenting objectives – the problem of pastoral management

The present public debate and on-going management strategies aiming to stimulate herders to increase slaughter by the use of economic subsidies, however, begs the question of what actually shape pastoral slaughter strategies (e.g. Næss *et al.* 2012). Næss & Bårdsen (2010, 2013), for example, argue that management initiatives may be based on a faulty assumption of what the objectives of reindeer herders are.

In contrast to the official subsidy policy, the concept of *risk* recognizes that pastoralists are not necessarily "[…] commercial ranchers geared to short-term profit maximization" (Borgerhoff Mulder and Sellen 1994:212). In general terms it may be that pastoralists view livestock as investments or 'banks on the hoof' that works as insurance against unpredictable environmental conditions:

> "*[h]erders thus continually increase numbers; selling fewer animals when prices are high enough to meet domestic demands and reluctantly selling more animals when prices are low* […]. *This is the antithesis of modern economics whereby high prices are assumed to stimulate higher production*" (Taylor 2006: 379, italics added).

In other words, pastoralists may follow a different logic than strict market logic where producers are expected to follow the 'law of supply', i.e. that when the price of a product rises suppliers should be willing to offer more of the product for sale (see Frank 2006). In Norway, for example, the average net kilo price for reindeer meat paid to owners has increased (Fig. S4.1) while at the same time reindeer abundance has increased.

Pastoralists' may thus balance the risk beneficial aspects of increasing herd size against economic gain through meat sales (Næss and Bårdsen 2010). Consequently, rather than expecting that slaughter strategies follow the law of supply, it may be that slaughter strategies follows a risk reducing logic. In short, when meat prices increases, *ceteris paribus*, pastoralists may slaughter less animals for the same financial gain as when prices are lower and thereby increase herd size. Interviews with Saami reindeer herders in Finnmark seem to support this notion: Johannesen and Skonhoft (2011:688) found that 51% of herders agreed or strongly agreed that herd size is an important risk reducing strategy and that units

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

agreeing with the insurance motive kept on average more animals than other herders. Pertinently, when asked how they would respond to long-lasting increases (doubling) in meat prices, herders who valued herd size as an insurance were less likely to increase slaughter compared to herders with no such motive (Johannesen and Skonhoft 2011:689).

Moreover, a previous study indicated that slaughter strategies are state-dependent: herders with the largest herd slaughtered more animals than herders with smaller herds (Næss *et al.* 2012). This can be explained with reference to risk: while wealthy herders are *risk averse* (i.e. loss minimisers) maintaining large herds through reducing the cost of reproduction (e.g. by controlling breeding rates, Mace 1993, or slaughtering calves, Næss *et al.* 2012), poor herders are *risk prone* (i.e. gain maximizers), i.e. maximizing herd size (e.g. by not controlling breeding rates or restricting calf slaughter).

Regional differences: risk management in the North and market economy in the South

The reindeer husbandry in Norway is characterized by regional variations, where the clearest contrasts, at least when it comes to reindeer abundance, is between the North (East- and West-Finnmark) and the South (South- and North-Trøndelag/Hedmark, Riseth 2003, Tveraa *et al.* 2007). In contrast to the North, the South has shown stable reindeer abundance from the 1960s to 1990 (Riseth and Vatn 2009:95). This difference still persist: while the North has experienced an overall increase in abundance, the South seems to have experienced a decrease (Fig. 1). Moreover, while the temporal trend in net meat kilo price is relatively similar (Fig. 1); there is a difference in calf slaughtering rates: herders in the South slaughter a larger proportion of their calves than herders in the North (Fig. 1). Surprisingly, important natural conditions are similar since both regions have access to winter pastures with cold, stable and favourable climate (Tveraa *et al.* 2007).

Tracing the historical diverging trends between the North and the South, Riseth and Vatn (2009:103) argues that herders in both regions were exposed to the same external changes after the Second World War, i.e. the introduction of new technologies, increased market access, and new state policies (for details about the newer history of the reindeer husbandry, see Næss and Bårdsen 2013:S1). Riseth and Vatn (2009:96) suggests that important reasons behind these regional differences in abundance may be related to how the aforementioned changes were handled by herders. Specifically, while the South is characterized by limited winter pastures and a more fragmented landscape, the North is characterized by open landscapes and summer pasture limitations (Riseth and Vatn 2009). Combined with a larger number of herders[3] in the North, the herders in the North are faced with larger challenges in relation to coordination of pasture use than herders in the South (Riseth and Vatn 2009). As such, competition for access to pastures may explain the adoption of herd accumulation in the North and not in the South (Næss *et al.* 2010). In relation to the policy of the Norwegian Government, Riseth and Vatn (2009:103) argues that while the process of herd growth started in the North before the new policies – aimed at reducing herd growth and to build a management system to better regulate the use of pastures – were implemented (late 1970s), the polices gave an extra push to enlarging herds. This because herders in the North found the new policies illegitimate and subsequent compromises between herders and the government ended in measures stimulating rather than curbing herd accumulation (Riseth and Vatn 2009). In contrast, restrictions on herd

[3] The total number of licensed herders in Finnmark nearly doubled from 1950 to 1990. Part of the increase in the 1980s was more formal than real as an extra registration of units were conducted to compensate for insufficient registrations in 1979 (Riseth and Vatn 2009:96-8). For Finnmark in general, number of licensed owners peaked in 1987 and has declined since (Hausner *et al.* 2011:fig. 2).

expansion were not controversial in the South as herders in the South seemed to have participated more actively in the political processes, which might have lead them to be more in line with governmental aims. Consequently, the new polices were well fitted to changes the Saami themselves were supporting, turning their focus towards increased production rather than herd accumulation (Riseth and Vatn 2009).

Predictions

To reiterate, whether pastoralists follow a market or risk logic entails different expected responses to increased meat prices. While a strict market logic predicts that producers should follow the 'law of supply', a risk logic predicts that when meat prices increases pastoralists can slaughter less animals for the same financial gain as when prices are lower and thereby increase herd size. This study thus investigated how the amount of slaughter undertaken by reindeer herders was influenced by: (1) own herd size, where we expected that herders with larger herds slaughter a larger proportion of their calves. (2) Meat price per kg, where we expected that as prices increases the proportion of calf slaughter decreases if risk management is the primary strategy. (3) Since wealthy herders are expected to be risk averse, and thereby reduce the cost of reproduction by slaughtering calves, we expected wealthy herders to be price insensitive. In other words, we expected a non-significant interaction between own herd size and meat price if risk management is important and state-dependent. (4) From a risk perspective we expected that as calf body mass increases the proportion of slaughter decreases since larger calves opens up for the possibility to slaughter fewer animals while receiving the same financial gain compared to herds consisting of smaller calves. (5) Consequently, we also expected a negative interaction between calf body mass and kilo meat prices, i.e. that increasing price and body mass work

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

together and decrease the proportion of slaughter. (6) Finally, we expected that herders in the South to be more market-oriented and less concerned with risk management compared to herders in the North.

MATERIALS AND METHODS

Ethics Statement

The data utilized in this study was provided by the Norwegian Institute of Nature Research as part of the participation in the project ECOPAST (http://pastoralism-climate-change-policy.com/projects/). The standard of ethics pertaining to the data has been approved by the Norwegian Social Science Data Services in connection with the project 'Beregning av produktivitet i reindrift' ('Calculation of productivity in the reindeer husbandry').

Study area

Saami reindeer husbandry has been said to be the cornerstone of the Saami culture in northern Fennoscandia (Bostedt 2001). Traditionally, reindeer pastoralism was based on families, or households that followed their herds year-round where the pastoral economy was primarily tied to reindeer products (Vorren 1978). The newer history of Saami reindeer husbandry can be summarized as being influenced by an increased meat and market adaptation coupled with an increased sedentarisation (Riseth 2006). During the late 1970s and onwards, the Norwegian Government became more and more directly engaged in the reindeer husbandry through subsidies and regulations. Reforms during the end of the 1970s and early 1980s aimed at increasing both production and co-management (Riseth and Vatn 2009) a trend that is still occurring. Sedantarisation, technological changes (primarily through the adoption of snowmobiles and later all-terrain vehicles during the late 1960s, see

Riseth and Vatn 2009) and the need to continuously maintain fences have significantly increased the cost of reindeer herding and thus increased the need for monetary income. According to Hausner et al. (2011) monetary income mainly comes from: (1) meat production; (2) governmental subsidies [found to range from 46% (Hausner *et al.* 2011:8) to ~50% (Berg 2008) of income]; and (3) spouses' wage income. A survey undertaken by Hausner et al. (2011:8-9) shows that 60% of respondents (n = 77) reported that wages from spouses are an important part of the household income, primarily from women since mostly men work daily with the herds.

From a national point of view, the Saami reindeer husbandry is a relatively small industry. Nevertheless, the Saami reindeer husbandry is important from a local and Saami point of view both in terms of economy and culture (Anonymous 2007). Moreover, around 40% of Norway's landmass is utilized by reindeer herders (Anonymous 2007). The reindeer husbandry in Norway is administered by the Ministry of Agriculture and Food and the Norwegian Agriculture Agency[4] (NAA). From a general point of view the reindeer husbandry is distinguished into six separate areas: (1) East-Finnmark; (2) Wes-Finnmark; (3) Troms; (4) Nordland; (5) North-Trøndelag; and (5) South-Trøndelag/Hedmark. Within these areas, the primary levels of social organization are: (1) districts – a formal management unit providing information to NAA; (2) siida – a cooperative unit composed of one to several families; and (3) siida-shares – the basic unit of the social organization consisting of a government license entitling the holder to practice reindeer herding (for more details, see Næss and Bårdsen 2013:S1).

[4] Formerly called the Reindeer Husbandry Administration.

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

In 2012 there was 545 siida-shares in Norway (386 of which are in Finnmark) with 3 097 persons affiliated with the siida-shares (Anonymous 2013). Table 1 shows descriptive statistics pertaining to the reindeer husbandry areas utilized in this study (see also Fig. 2).

Study protocol and statistical analyses

As in previous studies, e.g. Næss et al. (2011, 2012) and Næss and Bårdsen (2010, 2013), the data utilised by the study is based on governmental statistics compiled and published annually by the Norwegian Agriculture Agency (31st of March). This dataset contains data on herd size (total number of reindeer in the spring per siida-share), number of slaughtered calves, and number of marked calves covering the period 2000-2008. Additionally, the study utilised a second official dataset pertaining to regional average reindeer meat kilo prices (collected from Anonymous 2001, 2004, 2008b, 2010).

In contrast to previous studies that have only focused on Finnmark, this study utilized data from 37 summer districts from East- and West-Finnmark and North- and South-Trøndelag/Hedmark. As in previous studies we only included siida-shares with >70 reindeer[5]. Additionally, we only selected summer district with >2 siida-shares. Since we also were interested in siida-shares that do slaughter we only included units that slaughtered in the

[5] This selection was done to focus on herders that receive operating subsidies from the Norwegian Government since, as in Næss et al . (2009), we assume that operating subsidies reflect a high level of dependence on reindeer husbandry for making a living. To qualify for operating subsidies, siida shares have to produce a quota amount of reindeer meat for sale, i.e. the sale of reindeer meat with the value of 50 000 NOK (100 NOK=$12.97 per 04.03.15). See Næss et al. (2009:footnote 7) for details.

study (i.e. proportion calf slaughter >0)[6]. The utilized dataset contains the following variables:

Calf slaughter (response). -- A continuous (*siida-share level*) variable denoting the proportion of calves slaughtered each year. Calculated as the number of slaughtered individuals <1 year of age divided by the number of marked calves. Slaughtering takes place from September-March, main slaughter occurs in September, i.e. after calf marking and prior to the rut (Tveraa *et al.* 2013). We focus on the calves since they represent a significant proportion slaughter undertaken in the reindeer husbandry (Fig. 2B) as well as a strategic trade-off between meat production and herd accumulation.

N (predictor). -- A continuous (*siida-share level*) variable denoting the total spring herd size for each siida-share each year.

Kg price (predictor). -- A continuous (*regional level*) variable denoting the average net kilo reindeer meat price paid to herders from slaughterhouses each year. Denotes average prices received in East- and West-Finnmark and North- and South-Trøndelag/Hedmark respectively (Fig. 1).

Calf body mass (predictor). -- A continuous (*siida-share level*) variable denoting average calf carcass body mass for each siida-share each year (as reported by slaughterhouses).

[6] Næss et al. (2012) argues that decisions in relation to slaughter incorporate at least two decisions: (1) whether to slaughter or not; and (2) if slaughtering, the amount and type of animal(s) to slaughter. Næss et al. (2012) found that almost all herders slaughter at least one animal. Consequently, this study focuses only on herders that slaughtered. Moreover, as year was excluded as a covariate (see 'Confounding factors' section for rationale), all herders in this study would have slaughtered.

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

Region (predictor). -- A factor variable with *North* (baseline) and *South* acting as levels.

North designates East- and West-Finnmark while South designates North- and South-Trøndelag/Hedmark (see Fig. 2).

$ID_{district}$ (random variable). -- A factor variable labelling each summer district in the study and where each of the 37 districts acts as levels (see Fig. 2).

ID_{id} (random variable). -- A factor variable labelling each of the 638 siida-shares in the study as levels.

To statistically investigate whether slaughter strategies in the reindeer husbandry is: (1) state-dependent; (2) follows a risk or market logic; and (3) whether there are regional differences in risk vs. market logic we used the following model:

$$Calf\,slaughter = N + Kg\,price + Calf\,body\,mass + Region + N \times Kg\,price + Kg\,price \times Calf\,body\,mass + Kg\,price \times Region + Calf\,body\,mass \times Region + N \times Region$$

This structure was selected based on *a priori* expectations where (1) N and (2) *Kg price* represent state-dependency and risk vs. market respectively. (3) $N \times Kg\,price$ represent state-dependent price insensitivity. (4) *Calf body mass* and $Kg\,price \times Calf\,body\,mass$ represent, from a risk perspective, the ability for herders to reduce slaughter when both price and body mass increase. (5) *Region* and all two-way interactions represent regional differences in risk vs. market. Additionally, two three-way interactions ($N \times Kg\,price \times Region$ & $Kg\,price \times Calf\,body\,mass \times Region$) were included and excluded within the 'paradigm' of model selection using the Aikaike's Information Criterion (AIC: S1, see also e.g. Burnham and Anderson 2002).

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

We used linear mixed-effects models, with a random structure where ID_{id} was nested within $ID_{district}$, due to the inherent multilevel structure of the data (S1). The random effects in a mixed-effects model can conceptually be viewed as a way of controlling for additional sources of variation (or error) that we were otherwise unable to account for (Luke 2004).

Following the procedure described in Zuur et al. (2009) we selected the model with the lowest AIC value from a set of candidate models where the random structure varied (see S1 for details). Visual inspection of the residual plots from the model with the selected random structure indicated problems related to the homoscedastic assumption (Zuur *et al.* 2009). More to the point, the residual plot indicated that the variance increased as *Kg price* increased. Consequently, we also utilised model selection where we selected the model with the lowest AIC value from a set of candidate models with varying *variance structures* (with Kg price as the variance covariate`: S1, see also Zuur *et al.* 2009).

Statistical analyses and plotting of results were carried out in *R* (R Core Team 2014). All tests were two tailed, and the null hypothesis was rejected at an α level of 0.05; we used Wald statistics to test if estimated parameters were significantly different from zero (see also S1).

RESULTS

Northern slaughter strategies

For the northern region, we found a positive relationship between herd size and proportion of calves slaughtered, indicating that herders with larger herd size slaughtered a larger proportion of their calves than smaller herds (main effect of *N*, Table 2, Fig. 3A). In support of the market sensitivity hypothesis we found that price had a positive effect on the

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.
proportion of calf slaughtered, indicating that herders respond positively to price (main effect of *Kg price*: Table 2, Fig. 3B). In contrast, we found a non-significant interaction between herd size and price (effect of *N* × *Kg price:* Table 2). We also found that calf body mass had a negative, but statistically non-significant, effect on the proportion of calf slaughtered (main effect of *Calf body mass*: Table 2). Finally, we found a positive interaction between price and calf body mass (effect of *Kg price* × *Calf body mass*: Table 2). This effect was, however, small and non-significant (Table 2).

Southern slaughter strategies

We found that, on average, herders in the South slaughtered a larger proportion of their calves than in the North (main effect of *Region (South)*: Table 2). In fact, herders in the South slaughtered on average ~40% of their calves while herders in the North slaughtered only ~18% on average (exponent of Intercept and *Region (South)* in Table 2). We found, however, no significant difference in the effect of herd size in the North and South, i.e. herders with large herds slaughtered a larger proportion of their calves than herders with smaller herds in both regions [*N* × *Region (South)* interaction which was nearly significant*:* Table 2, Fig 3A & 4A]. We also found a negative interaction between price and region [effect of *Kg price* × *Region (South)*: Table 2]. While price had a positive effect on the proportion of calf slaughtered in the North, the negative interaction was so large that for herders in the South the effect of price became negative (Fig. 4B). In other words, in contrast to the expectation that herders in the South should be more market oriented and thus respond positively to increased prices, we found the opposite: as prices increased, herders in the South slaughtered less. Nevertheless, the effect of price was dependent on both herd size and calf

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.
body mass [effect of *N* × *Kg price* × *Region (South)* and *Kg price* × *Calf body mass* × *Region (South)*, Table 2]. While herd size had no effect on the *direction* of the effect of price (Fig. 4B), the effect of price changed from negative to positive for low and high calf body mass respectively (Fig. 4D). We also found a strong and positive interaction between calf body mass and region [*calf body mass* × *Region (South)*: Table 2] indicating that herders in the South slaughtered a larger proportion of their calves when calf body mass was high compared to herders in the North (Fig. 4C). The fact that the effect of price changed from negative to positive depending on the size of the calves coupled with the fact that calf body mass had a positive effect on the proportion of calves slaughtered supported the hypothesis that herders in the South are more market-oriented and less concerned with risk management compared to herders in the North.

DISCUSSION

The concept of risk highlights a different logic than strict market logic, where producers are expected to follow the 'law of supply'. For example, considering the risk beneficial aspects of having a large herd (e.g. Næss 2009, Næss and Bårdsen 2010, Næss and Bårdsen 2013), increased meat prices make it possible for pastoralists to slaughter fewer animals for the same financial gain as when prices are low and subsequently convert un-slaughtered animals to herd capital.

Nevertheless, the result from this study indicates that pastoralists follow a logic that is shaped by neither risk nor market considerations alone, but rather a combination because in the North, for example, slaughter strategies are shaped by both herd size and price. While the fact that Northern herders slaughter more reindeer when having a large herd size supports the predominance of a risk logic, the fact that they slaughter more reindeer as prices increases indicates the presence of a market logic. Nevertheless, the positive effect of price has to be viewed in concert with the average level of slaughter in the North: compared with their Southern counterparts, herders in the North slaughter on average a substantially lower proportion of their calves. While price had a positive effect, it never had a large enough effect so that the predicted slaughter equalled the average level of slaughter in the South. In other words, herders in the North have a baseline more risk-oriented slaughter strategy compared to the South. As such, it is doubtful that slaughter strategies in the North are primarily shaped by market considerations.

In contrast to herders in the North, slaughter strategies in the South seem to be more complex. While herders in the South were similarly affected by herd size as herders in the North (i.e. herders' with the largest herds slaughtered a larger proportion of their calves in both regions), herders in the South with larger calves slaughtered a larger proportion of their calves than herders with smaller calves. From a risk point of view, the opposite was expected: higher calf body mass make it possible to slaughter fewer animals while receiving the same financial gain compared with when calf body mass is lowered. This pattern – together with the average high level of calf slaughter – indicates that slaughter strategies in the South are predominantly shaped by market considerations. The effect of price, however, seems to contradict this: as prices increased, herders in the South slaughtered a smaller proportion of their calves than at lower prices. This seems to support a risk logic: as prices increases herders may slaughter fewer animals in order to receive a similar financial gain compared to a situation with lower prices and thereby increase herd size. Nevertheless, the effect of price has to be interpreted in the light of the fact that herders in the South already slaughter, on average, a larger proportion of their calves irrespective of price. More importantly, the effect of price has to be viewed in light of both calf body mass and herd size. At large herd sizes the

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.
negative effect of price became weaker indicating that wealthy herders are to some degree price sensitive in the South, but this effect never became positive. This changed, however, when considering the effect of price in concert with calf body mass: herders with larger calves responded positively to increasing prices. In other words, the effect of price changed from negative to positive when calves were large. This again supports the market logic hypothesis rather than the risk hypothesis.

Differential value of pastoral products – pastoralists and the market

Khazanov (1994) has argued that nomadic pastoralists are primarily oriented towards subsistence production. Consequently, integration into a market economy will put undue stress on their economy because the traditional technologies of a subsistence-based economy cannot keep up with the demands of a surplus market (Khazanov 1994). Moreover, the commercialization of livestock and livestock products has been viewed as a modern invention and not part of the "traditional" way of life (cf. Marx 2006). In contrast, Marx (2006) has argued that pastoralists do produce, at least to some degree, for markets, and always have. Nevertheless, the distinction between subsistence and commercial pastoralism is difficult and can only by ascertained by looking at long-term strategies (Behnke 1987). For example, it has been argued that one of the most puzzling features of pastoral behavior is the apparent low and responsive rate of market related off-take when facing a high probability of herd losses (e.g. beginning of droughts, Barrett *et al.* 2004). In short, by converting environmental induced mortality into sales, pastoralists can reduce the negative impacts of catastrophes as well as accelerate herd recuperation when conditions have improved (Barrett *et al.* 2004). While pastoralists in northern Kenya and southern Ethiopia have been found to participate actively in livestock markets, there is no strong price response in terms of sales, rather pastoralists seem to balance the benefits of long-term herd accumulation objectives with short-term consumption or cash objectives when deciding whether and what to sell (Barrett *et al.* 2004). This indicates not only that the underlying objectives for pastoralists may significantly deviate from market related meat production (Næss and Bårdsen 2010, Næss and Bårdsen 2013, Næss *et al.* 2011, Næss *et al.* 2012), but also that livestock have different values than purely market related cash values. In a review of the economic contributions of pastoralism in Africa, Behnke (2008:72) concludes that "[…] the undervaluing of pastoralism in national accounts rests on two recurrent methodological flaws – underestimation of the cash value of subsistence production and incomplete recording of the different kinds of pastoral output". Additional value from livestock may include: (1) outputs that are used as inputs in other activities (manure or traction power in crop farming); (2) outputs that are directly consumed by households (milk and dairy products); or (3) accumulated as a store of capital (live animals). In short, Behnke (2008) argues that these are all benefits that do not have an obvious cash value. More to the point, these are values that may not easily be converted to cash, but may be very important for pastoralists. For reindeer herders this might very well entail balancing the risk beneficial value of live animals with one-time cash value of slaughtered reindeer (Næss *et al.* 2011).

Body mass vs. herd accumulation – the complexity of pastoral risk management

Næss et al. (2010) hypothesized that, from a risk perspective, the best long-term strategy may be to invest in livestock body mass and not in herd size (see also Næss 2013, Næss and Bårdsen 2010, Næss and Bårdsen 2013). For example, it is relatively well known that density has a negative effect on herbivore body mass (Albon *et al.* 1983, Clutton-Brock *et al.* 1996, Sæther 1997). As for reindeer, evidence indicates that population density and climatic conditions have negative effects on individual body mass (Bårdsen *et al.* 2014, Bårdsen 2009, Bårdsen *et al.* 2011, Bårdsen and Tveraa 2012, Næss *et al.* 2009, Tveraa *et al.* 2007) and, consequently, survival (Tveraa *et al.* 2003). Increased density also increases herders' vulnerability to unfavourable climate as the negative impacts of adverse climatic events increases with increasing reindeer density (Bårdsen *et al.* 2010, Bårdsen *et al.* 2011, Bårdsen and Tveraa 2012). The adoption of herd accumulation may thus depend more on competition rather than being the best risk management strategy (Næss *et al.* 2010). In a competitive environment, where access to grazing is to a large degree dependent on herd size (since larger herds use more extensive pasture areas and thus may exclude other herds from grazing in the same area, Næss *et al.* 2010), restricting slaughter, or at least synchronise slaughter with neighbouring herders (Næss *et al.* 2012), may thus be the best available option. For Northern herders, where coordination have been argued to be problematic (Riseth and Vatn 2009), herd accumulation may be the only viable risk-reducing strategy. Following this line of thought, the on average high proportional calf slaughter among Southern herders compared to the herders in the North may also be interpreted as a risk management strategy rather than a market oriented strategy. In environments with little or no competition, as in the South, a high proportional offtake might offset the negative effect of density on body mass and thus reduce herders' vulnerability to unfavourable climate. Pertinently, calf carcass body mass is significantly lower in the North than in the South, an effect that is exacerbated over time (Fig. 5 and Table S4.1).

Confounding factors

Assessing uncertainties in the temporal development of prices

An important question is whether reindeer herders actually have received more money as a consequence of increased prices. The problem is that the measure of price published by the NAA varies: From 1997 to 2003, their published measure of price reflects *net* prices paid to herders from slaughterhouses. From 2003/2004 and onwards this measure changes to the *gross* price paid to herders from slaughterhouses, i.e. the cost of slaughtering (and transport costs) is included in the measure (the herders are subsequently billed for this cost, Anonymous 2005b:8-9)[7]. Furthermore, there have apparently been errors that can be tracked back to 2006 in the reports provided by the slaughterhouses. Consequently, the reported price measure has been artificially high for some years, i.e. income from meat sale has been overestimated (Anonymous 2010:9-10). While the errors have been rectified, correct measures are only valid from 2009 and onwards. In other words, the measure of price paid to herders published by the NAA may not represent an actual increase in meat prices.

Nevertheless, looking at consumer prices there are strong indications that there actually has been an increase: from 1996-2001 consumer prices increased, while from 2002-2005 it stayed mostly the same (Fig. 6 A). Moreover, while data pertaining to consumer price does not cover the whole time period of the study, there is a strong relationship between consumer prices and the price reported by slaughterhouses as paid to reindeer herders per

[7] A survey of the slaughterhouses doing this, undertaken by the former Reindeer Husbandry Administration, indicates that the costs are around 5-10 NOK per kg. From 2004 the cost of transporting is also included for some of the slaughterhouses. (Anonymous 2005b:9)

kg meat (Fig. 6 B). This relationship indicates that the price measure used in this study represents a good proxy for the economic value of reindeer meat and that this measure reflects a real increasing value of reindeer meat. Nevertheless, the result from this study should be interpreted with caution since the data do not seem to straightforwardly suggest whether a real increase in meat value (i.e. increased consumer price) was translated into more money to herders or not.

Confounding and multicollinearity

Observational studies have potential problems in relation to confounding that may lead to spurious relationships between the included predictors and the response as well as biased estimates (Cohen *et al.* 2003). Problems related to confounders were, however, reduced as we had *a priori* expectations to all predictors included in the analyses (Burnham and Anderson 2002, Anderson 2008). Nevertheless, there are several important factors not included in our models that can potentially influence slaughtering. First, variation in climate may affect slaughtering as survival is particularly constrained during harsh winters (Tveraa *et al.* 2003), and husbandry units experiencing harsh winter conditions may be reluctant to slaughter. While this needs to be further investigated, reindeer populations seem not to be severely limited by negative winter conditions since the overall reindeer abundance in Norway has increased from ~2001 and onwards (Bårdsen *et al.* 2010, Næss and Bårdsen 2013, Næss and Bårdsen 2010, Næss *et al.* 2011). For the North and South reindeer abundance have increased from 2002 and 2004 respectively (Fig. 1 A and B). Moreover, while the winters of 1997 and 2000 has been described as catastrophic (Hausner *et al.* 2011) partially contributing to a low point in reindeer abundance in 2001 (Næss and Bårdsen 2013), the total amount of slaughter undertaken by reindeer herders have been increasing from 1997 to 2007 on a national level (Fig. S4.2). As such, the inability to account for possible negative effects of winter climate should not severely affect our conclusions.

Second, temporal trends in the number of animals slaughtered can confound our analyses. There is for example a positive temporal trend in amount of slaughter in the North, while in the South the trend is negative (Fig. S4.3) indicating that year is an important predictor. While year was not included as a covariate, by including herd size we did partially control for such temporal trends due to the positive association between herd size and year, which is apparent at the national level (Næss *et al.* 2011) as well as for many districts (Bårdsen *et al.* 2010, Tveraa *et al.* 2007) and husbandry units (Næss and Bårdsen 2010, Bårdsen *et al.* 2014). Moreover, year and price was positively correlated (see S2) indicating that we could have substituted price with year in the analyses. Year is, however, arguably more of a black-box that does not have the same potential for providing a mechanistic explanation as price (or the other predictors used in the study), which were included based on *a priori* considerations. As we had explicit *a priori* predictions to both price and herd size, we thus chose to include price in the analyses as a covariate and not year. Including both year and price would result in multicollinearity issues (for discussions pertaining to the reindeer husbandry and multicollinearity, Næss and Bårdsen 2010, Næss *et al.* 2011, Næss *et al.* 2009).

Third, both mortality and reproduction are important potential confounders as they may influence slaughter strategies. As Næss et al. (2012) argue, by including herd size this problem is reduced since both the number reindeer born and die during a year are related to herd size.

Fourth, variation in vegetation quantity and quality may have important consequences for slaughtering since good pasture conditions may lead to an increased calf

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.
production (e.g. Bårdsen and Tveraa 2012). While we have not explicitly controlled for this source of variation, we controlled for some measure of between-district variations by including districts as a random effect in our analyses (cf. Næss *et al.* 2009).

MANAGEMENT IMPLICATIONS

Næss & Bårdsen (2010, 2013) and Næss et al. (2011, Næss *et al.* 2012) argue that present management initiatives in relation to the reindeer husbandry may be based on a faulty assumption of what the objectives of reindeer herders are, rather it is assumed that reindeer herders are meat producers maximizing monetary income through slaughter. Economic subsidies is a case in point, they aim at stimulating slaughter by adding a monetary bonus when slaughtering. Subsidies will of course work most efficiently if herders are motivated by monetary gains. Nonetheless, production subsidies do not seem to properly account for the decision problem facing herders: how to secure a reliable income while at the same time maximizing long term survival in a variable environment. From this point of view, the rational strategy may be to slaughter a minimum number of animals for monetary gain while investing the rest in herd size to maximize long-term survival. If this is true, subsidies will increase the monetary gain per animal and thus reduce the number animals herders have to slaughter. It may even be argued that management initiatives do not correctly account for the reindeer herders' time frames and time-discount functions (e.g. Borgerhoff Mulder and Sellen 1994). Restricting slaughter now may be sub-optimal in the short run if we assume that herders maximize financial gain. In the long run, however, a conservative slaughter strategy may be optimal since herders with larger herds perform better than herders with comparable smaller herds both on a year-to-year basis (Næss and Bårdsen 2010) and during crisis periods (Næss and Bårdsen 2013). The results from this study seem to support the

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

hypothesis that pastoral slaughter strategies entails balancing the risk beneficial aspects of increasing herd size against economic gain through meat sales (Næss and Bårdsen 2010, Næss and Bårdsen 2013, Næss *et al.* 2011), at least for herders in the North. In other words, the result from this study indicates that pastoralists follow a logic that is shaped by neither risk nor market considerations alone, but rather a combination. Importantly, it should be noted that

> "[w]hilst improvement in production and commercialisation remain important goals, livestock policy needs to concentrate more on pastoralist needs, which are not always market centred, and certainly not always oriented towards maximising off take. *Policies should not be framed on the assumption that any change in the production system will automatically benefit pastoralism*" (Hatfield and Davies 2006: 28. Italics added).

ACKNOWLEDGMENTS

Funding for this study was provided by the Research Council of Norway (grant number: 204174 and 240280/F10). We thank the Reindeer Husbandry Administration for access to data and Torkild Tveraa for preparing the data prior to the statistical analyses. We would also like to thank two anonymous reviewers for improving the manuscript.

REFERENCES CITED

Aiken, L. S., and West, S. G. (1991). Multiple regression: testing and interpreting interactions, Sage, Newbury Park, Calif.

Albon, S. D., Mitchell, B., and Staines, B. W. (1983). Fertility and Body-Weight in Female Red Deer - A Density-Dependent Relationship. Journal of Animal Ecology 52(3):969-980.

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

Anderson, D. R. (2008). Model based inference in the life sciences: a primer on evidence, Springer Science, New York, United States of America.

Anonymous. (2001). Totalregnskap for reindriftsnæringen. Reindriftsforvaltningen, Alta, Norway, pp. p. 145.

—. (2004). Totalregnskap for reindriftsnæringen. Reindriftsforvaltningen, Alta, Norway, pp. p. 143.

—. (2005a). "St.prp. nr. 63: Om reindriftsavtalen 2005/2006, om dekning av kostnader vedrørende radioaktivitet i reinkjøtt, og om endringer i statsbudsjettet for 2005 m.m. ," pp. 36: Det Kongelige Landbruks- og Matdepartement.

—. (2005b). Totalregnskap for reindriftsnæringen. Reindriftsforvaltningen, Alta, Norway, pp. p. 141.

—. (2007). Reindrift. The Directorate for Nature Management, Norway http://www.dirnat.no/content.ap?thisId=1009878 Accessed: 08.06.2009

—. (2008a). Ressursregnskap for reindriftsnæringen. Reindriftsforvaltningen,, Alta, Norway, pp. p.164.

—. (2008b). Totalregnskap for reindriftsnæringen. Reindriftsforvaltningen, Alta, Norway, pp. p. 126.

—. (2010). Totalregnskap for reindriftsnæringen. Reindriftsforvaltningen, Alta, Norway, pp. p. 132.

—. (2013). Ressursregnskap for reindriftsnæringen. Reindriftsforvaltningen, , Alta, Norway, pp. p. 105.

Barrett, C. B., McPeak, J. G., Luseno, W., Little, P. D., Osterloh, S. H., Mahmoud, H., and Gebru, G. (2004). "Pastoralist Livestock Marketing Behavior in Northern Kenya and Southern Ethiopia: An Analysis of Constraints Limiting Off-take Rates," in Economics Faculty Scholarship.

Behnke, R. H. (1987). Cattle Accumulation and the Commercialization of the Traditional Livestock Industry in Botswana. Agricultural Systems 24(1):1-29.

Behnke, R. H. (2008). The Economic Contribution of Pastoralism: Case Studies from the Horn of Africa and Southern Africa. Nomadic Peoples 12(1):45-79.

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

Berg, B. Å. (2008). Utviklingen av reindriften i nordre Nordland 1750-2000. In B. Evjen and L. I. Hansen (eds.), Nordlands kulturelle mangfold: etniske relasjoner i historisk perspektiv, Pax, Oslo, pp. 151-191.

Bjørklund, I. (1990). Sami Reindeer Pastoralism as an Indigenous Resource Management System in Northern Norway: A Contribution to the Common Property Debate. Development and Change 21:75-86.

Borgerhoff Mulder, M., and Sellen, D. W. (1994). Pastoralist decision making: A behavioral ecological perspective. In E. Fratkin, K. A. Galvin, and E. A. Roth (eds.), African Pastoralist Systems: An Integrated Approach, Boulder, London, pp. 205-229.

Bostedt, G. (2001). Reindeer husbandry, the Swedish market for reindeer meat, and the Chernobyl effects. Agricultural Economics 26(3):217-226.

Burnham, K. P., and Anderson, D. R. (2002). Model selection and multimodel inference: a practical information-theoretic approach, Springer, Inc., New York, USA.

Bårdsen, B.-J. (2009). Risk sensitive reproductive strategies: the effect of environmental unpredictability. Philosophiae Doctor, University of Tromsø.

Bårdsen, B.-J., Henden, J.-A., Fauchald, P., Tveraa, T., and Stien, A. (2011). Plastic reproductive allocation as a buffer against environmental stochasticity – linking life history and population dynamics to climate. Oikos 20:245-257.

Bårdsen, B.-J., Næss, M. W., Tveraa, T., Fauchald, P., and Langeland, K. (2014). Risk-sensitive reproductive allocation: fitness consequences: of body mass losses in two contrasting environments. Ecology and Evolution 4(7):1030–1038.

Bårdsen, B.-J., and Tveraa, T. (2012). Density dependence vs. density independence – linking reproductive allocation to population abundance and vegetation greenness. Journal of Animal Ecology 81(2):364-376.

Bårdsen, B. J., Tveraa, T., Fauchald, P., and Langeland, K. (2010). Observational evidence of a risk sensitive reproductive allocation in a long-lived mammal. Oecologia 162:627-639.

Clutton-Brock, T. H., Stevenson, I. R., Marrow, P., MacColl, A. D., Houston, A. I., and McNamara, J. M. (1996). Population fluctuations, reproductive costs and life-history tactics in female Soay sheep. Journal of Animal Ecology 65(6):675-689.

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

Cohen, J., Cohen, P., West, S. G., and Aiken, L. S. (2003). Applied multiple regression/correlation analysis for the behavioral sciences, 3rd edition, Lawrence Erlbaum, Mahwah, N.J.

Frank, R. H. (2006). Microeconomics and behavior, 6th edition, McGraw-Hill/Irwin, Boston, Mass.

Fratkin, E., and Roth, E. A. (1990). Drought And Economic Differentiation Among Ariaal Pastoralists Of Kenya. Human Ecology 18(4):385-402.

Hatfield, R., and Davies, J. (2006). Global Review of the Economics of Pastoralism. The World Initiative for Sustainable Pastoralism. IUCN, Nairobi, pp. 44.

Hausner, V. H., Fauchald, P., Tveraa, T., Pedersen, E., Jernsletten, J.-L. L., Ulvevadet, B., Ims, R. A., Yoccoz, N., and Bråthen, K. A. (2011). The Ghost of Development Past: the Impact of Economic Security Policies on Saami Pastoral Ecosystems. Ecology and Society 16(3):4 http://dx.doi.org/10.5751/ES-04193-160304.

Herskovits, M. J. (1926). The Cattle Complex in East Africa. American Anthropologist 28(4):633-664.

Johannesen, A. B., and Skonhoft, A. (2011). Livestock as Insurance and Social Status: Evidence from Reindeer Herding in Norway. Environmental & Resource Economics 48(4):679-694.

Khazanov, A. M. (1994). Nomads and the outside world, 2nd edition, University of Wisconsin Press, Madison.

Lamprey, H. (1983). Pastoralism Yesterday and Today: the Overgrazing Problem. In F. Bourliers (eds.), Ecosystems of the World 13: Tropical Savannas, Elsevier Scientific Publishing Co, Amsterdam.

Larsson, C.-G., and Ballovara, M. (2013). Støtter tvangstiltak for å få ned reintallet. NRK. http://www.nrk.no/kanal/nrk_sapmi/1.10886044 Accessed:

Luke, D. A. (2004). Multilevel modeling. Quantitative applications in the social sciences, Sage Publications, Thousand Oaks, Calif.

Mace, R. (1993). Nomadic pastoralists adopt subsistence strategies that maximise long-term household survival. Behavioral Ecology and Sociobiology 33:329-334.

—. (1996). Biased parental investment and reproductive success in Gabbra pastoralists. Behavioral Ecology and Sociobiology 38(2):75-81.

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

Mace, R., and Houston, A. (1989). Pastoralist strategies for survival in unpredictable environments: A model of herd composition that maximises household viability. Agricultural Systems 31(2):185-204.

Marx, E. (2006). The Political Economy of Middle Eastern and North African Pastoral Nomads. In D. Chatty (eds.), Nomadic societies in the Middle East and North Africa entering the 21st century, Brill, Leiden, pp. 78-97.

McCabe, J. T. (2004). Cattle bring us to our enemies : Turkana ecology, politics, and raiding in a disequilibrium system. Human-environment interactions, University of Michigan Press, Ann Arbor, Mich.

McPeak, J. (2005). Individual and collective rationality in pastoral production: Evidence from Northern Kenya. Human Ecology 33(2):171-197.

Næss, M. W. (2009). Pastoral Risk Management - The Importance of Cooperative Production. PhD, University of Tromsø, Norway.

—. (2012). Cooperative Pastoral Production: Reconceptualizing the Relationship between Pastoral Labor and Production. American Anthropologist 114(2):309-321.

—. (2013). Climate Change, Risk Management and the End of *Nomadic* Pastoralism. International Journal of Sustainable Development and World Ecology 20(2):123-133.

Næss, M. W., and Bårdsen, B.-J. (2010). Environmental Stochasticity and Long-Term Livestock Viability-Herd-Accumulation as a Risk Reducing Strategy. Human Ecology 38(1):3-17.

Næss, M. W., and Bårdsen, B.-J. (2013). Why Herd Size Matters – Mitigating the Effects of Livestock Crashes. Plos One 8(8): e70161.

Næss, M. W., Bårdsen, B.-J., Fauchald, P., and Tveraa, T. (2010). Cooperative pastoral production - the importance of kinship. Evolution and Human Behavior 31(4):246-258.

Næss, M. W., Bårdsen, B.-J., Pedersen, E., and Tveraa, T. (2011). Pastoral herding strategies and governmental management objectives: predation compensation as a risk buffering strategy in the Saami reindeer husbandry. Human Ecology 39(4):489-508.

Næss, M. W., Bårdsen, B.-J., and Tveraa, T. (2012). Wealth-dependent and interdependent strategies in the Saami reindeer husbandry, Norway. Evolution and Human Behavior 33(6):696-707.

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

Næss, M. W., Fauchald, P., and Tveraa, T. (2009). Scale Dependency and the "Marginal" Value of Labor. Human Ecology 37(2):193-211.

OAGN. (2012). "Riksrevisjonens undersøkelse av bærekraftig bruk av reinbeiteressursene i Finnmark - Dokument 3:14 (2011–2012)," Office of the Auditor General of Norway, pp. 89: Office of the Auditor General of Norway.

Paine, R. (2009). Camps of the tundra: politics through reindeer among Saami pastoralists. Instituttet for sammenlignende kulturforskning. Serie B, Skrifter, Instituttet for sammenlignende kulturforskning, Oslo.

R Core Team. (2014). R: A language and environment for statistical computing.

Riseth, J. Å. (2003). Sami Reindeer Management in Norway: Modernization Challenges and Conflicting Strategies. Reflections Upon the Co-management Alternative. In S. Jentoft, H. Minde, and R. Nilsen (eds.), Indigenous Peoples: Resource Management and Global Rights, Eburon Academic Publishers, Delft, Netherlands, pp. 229-247.

—. (2006). Sàmi reindeer herd managers: why do they stay in a low-profit business? British Food Journal 108(7):541-559.

Riseth, J. Å., and Vatn, A. (2009). Modernization and Pasture Degradation: A Comparative Study of Two Sàmi Reindeer Pasture Regions in Norway. Land Economics 85(1):87-106.

Somby, L. I. (2013). Frykter sabotasje og intern strid. NRK. http://www.nrk.no/kanal/nrk_sapmi/1.10893374 Accessed:

Sæther, B. E. (1997). Environmental stochasticity and population dynamics of large herbivores: A search for mechanisms. Trends In Ecology & Evolution 12(4):143-149.

Taylor, J. L. (2006). Negotiating the grassland: The policy of pasture enclosures and contested resource use in Inner Mongolia. Human Organization 65(4):374-386.

Templer, G., Swift, J., and Payne, P. (1993). The changing significance of risk in the Mongolian pastoral economy. Nomadic Peoples 33:105-122.

Tveraa, T., Fauchald, P., Henaug, C., and Yoccoz, N. G. (2003). An examination of a compensatory relationship between food limitation and predation in semi-domestic reindeer. Oecologia 137(3):370-376.

Tveraa, T., Fauchald, P., Yoccoz, N. G., Ims, R. A., Aanes, R., and Hogda, K. A. (2007). What regulate and limit reindeer populations in Norway? Oikos 116(4):706-715.

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

Tveraa, T., Stien, A., Bardsen, B. J., and Fauchald, P. (2013). Population Densities, Vegetation Green-Up, and Plant Productivity: Impacts on Reproductive Success and Juvenile Body Mass in Reindeer. Plos One 8(2).

Ulvevadet, B. (2012). The governance of Sami reindeer husbandry in Norway: institutional challenges of co-management, University of Tromsø, Faculty of Biosciences, Fisheries and Economics, Norwegian College of Fishery Science, Tromsø.

Ulvevadet, B., and Hausner, V. H. (2011). Incentives and regulations to reconcile conservation and development: Thirty years of governance of the Sami pastoral ecosystem in Finnmark, Norway. Journal of Environmental Management 92(10):2794-2802.

Vorren, Ø. (1978). Bosetning og ressursutnytting i ressursutvalgets mandatområde under veidekulturen og dens differensiering, Universitetsbiblioteket i Tromsø (in Norwegian), Tromsø.

Wood, S. N. (2012) mgcv: GAMs with GCV/AIC/REML smoothness estimation and GAMMs by PQL. R package version 1.8.0.

Zuur, A. F., Ieno, E. N., Walker, N., Saveliev, A. A., and Smith, G. M. (2009). Mixed effects models and extensions in ecology with R, Springer-Verlag New York, New York, NY.

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

TABLES

Table 1. Descriptive data for the areas used in the analyses (per 31st March 2012. source: Anonymous 2013).

Region	Districts†	Siida-shares	Persons‡	Summer siidas	Winter siidas
North					
East-Finnmark	10	175	909	19	51
West-Finnmark	23	210	1450	36	53
South					
North-Trøndelag	6	39	188	10	10
South-Trøndelag/Hedmark	5	30	149	4	4

† From number of letter codes on maps presented in Anonymous (2013:92-105)

‡ Number of persons affiliated with siida-shares, e.g. people who may have an earmark in a siida-share but does not have a license.

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

Table 2. Estimates from linear mixed effect models relating proportion of calf slaughter (*Calf slaughter*) as a function of herd size (*N*), price (*Kg price*), calf carcass body mass (*Calf body mass*), region (*Region*), their two-way interactions as well as two three-way interactions.

Parameter	Response: *Calf slaughter (proportion)* †			
	Value	(95% CI)	df	*p*
Fixed effects				
Intercept	-1.719	(-1.963, -1.475)	2352	<0.001
N‡	0.250	(0.147, 0.352)	2352	<0.001
Kg price‡	0.030	(0.025, 0.035)	2352	<0.001
Calf body mass‡	-0.167	(-0.476, 0.142)	2352	0.290
Region (South)	0.794	(0.248, 1.340)	35	0.006
N × *Kg price*	-0.002	(-0.009, 0.005)	2352	0.579
Kg price × *Calf body mass*	0.008	(-0.018, 0.034)	2352	0.540
Kg price × *Region (South)*	-0.047	(-0.053, -0.041)	2352	<0.001
Calf body mass × *Region (South)*	1.052	(0.443, 1.661)	2352	0.001
N × *Region (South)*	0.202	(-0.009, 0.412)	2352	0.061
N × *Kg price* × *Region (South)*	0.017	(0.007, 0.026)	2352	0.001
Kg price × *Calf body mass* × *Region (South)*	0.075	(0.035, 0.115)	2352	<0.001
Random effects (i.e. random intercepts fitted per group)				
Among $ID_{district}$ SD	0.636	(0.489, 0.827)	n_{obs} =	37
Among ID_{id} in $ID_{district}$ SD	0.521	(0.469, 0.579)	n_{obs} =	368
Within group SD (residuals)	0.382	(0.306, 0.476)	n_{obs} =	2730
Variance structure (VarComb)				
Region SD (South as baseline)				
North	3.323	(3.070, 3.596)		
Exponent (*Kg price*)	-0.008	(-0.012, -0.005)		

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

† $\log_e$-transformed.

‡ $\log_e$-transformed and centred (substracting the average, see Aiken and West 1991:35).

NOTE: One observation was removed because it was considered an outlier. The exclusion of the observation had no impact on the significance or direction of the parameter estimates in the presented model and thus the inclusion or exclusion of the observation did not affect the inferences presented. The results presented here is from a model with the observation excluded.

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

FIGURES

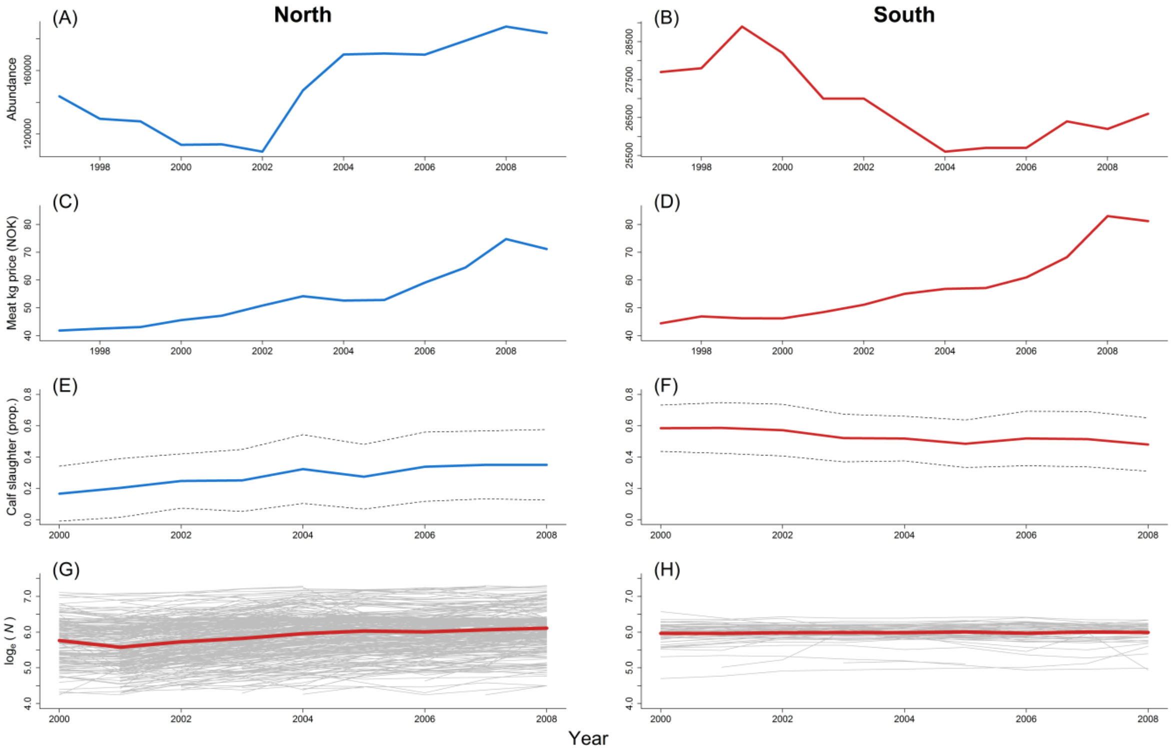


Fig. 1. Temporal trends for the North (left panel) and South (right panel) for: (A and B) reindeer abundance; (C and D) average meat prices per kg; (E and F) average proportion calf slaughtering relative to the number of marked calves (hatched lines indicate ± 1 SD); and (G and H) herd size (grey lines indicates temporal trends for individual siida shares, while thick line shows annual average). Source: Anonymous (2001, 2004, 2008b, 2010) and regional aggregated data of the data used in the analyses.

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

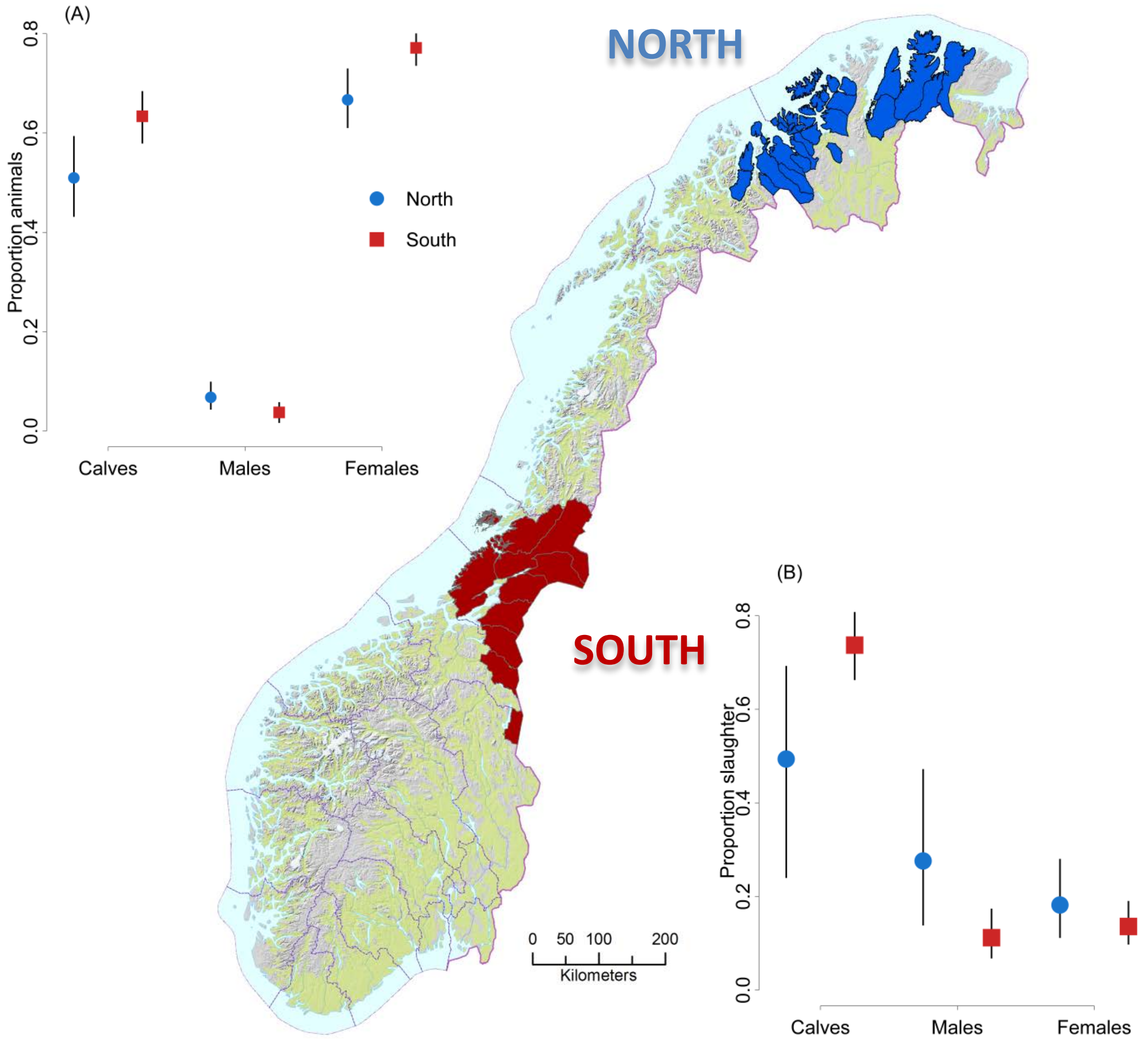


Fig 2. Map over the study area (Source: Background map: Norwegian Mapping Authority, Geovekst and Municipalities). (A) The proportion of calves, adult males and adult female reindeer among reindeer herds in the North (circle) and the South (square) and (B) the proportion of calves, adult males and adult females slaughtered of total slaughter in the North (circle) and the South (square). The circle and square indicates median values across herds and years, while lines indicate the 25th and 75th quartile (*n* = 2457 for the North and *n* = 461 for the South).

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

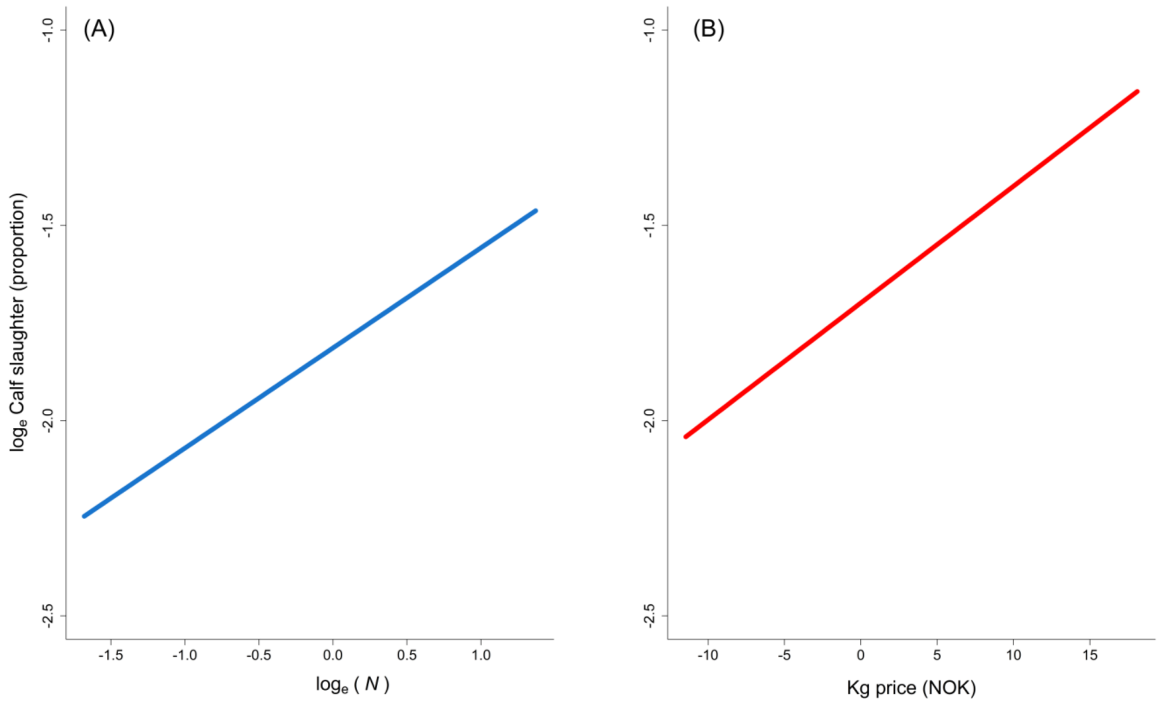
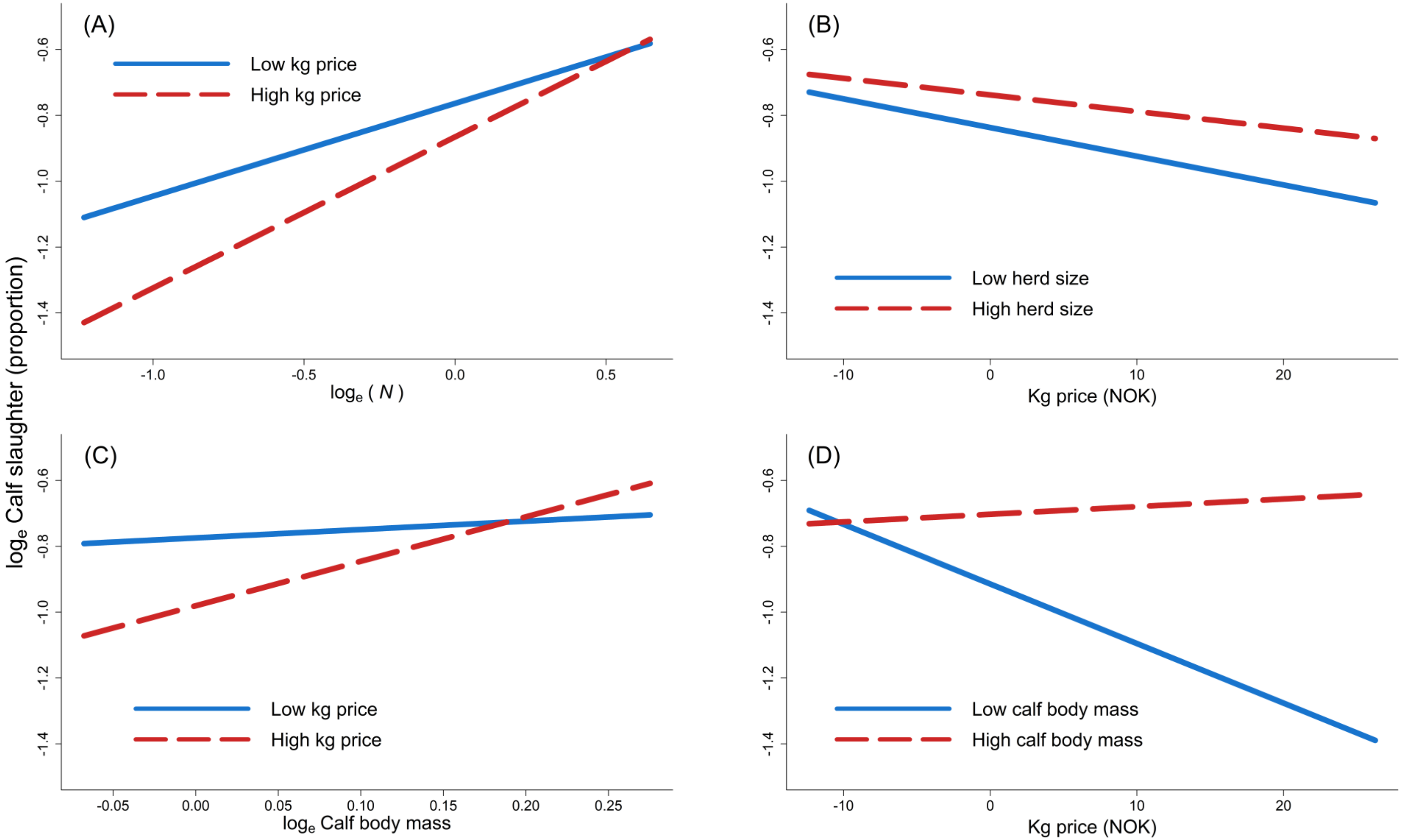


Figure 3. A visualisation of the relationship (using centred predictors) between herd size and meatprice and proportion of calf slaughtered based on the model presented in Table 2 for the northern region. (A) The effect of herd size where calf body mass and price was set to their average values while (B) shows the effect of price where herd size and calf body mass was set to their average values. This because only herd size and price alone had any significant effect on proportion of calf slaughtered (Table 2).

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.



Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

Figure 4. A visualisation of the relationship between herd size, price and calf body mass and proportion of calf slaughtered (using centred predictors) based on the model presented in Table 2 for the South. (A) The effect of herd size at low (25th percentile) and high (75th percentile) values for price but when body mass was set to its average. (B) The effect of price at low (25th percentile) and high (75th percentile) values for herd size and average body mass. (C) The effect of calf body mass at low and high price values where average herd size was used. (D) The effect of price at low calf body mass and where herd size was set to its average value. To show how the price-effect changed from negative to positive depending on body mass, calf body mass was set to the 5th and 95th percentile respectively (see also S3).

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

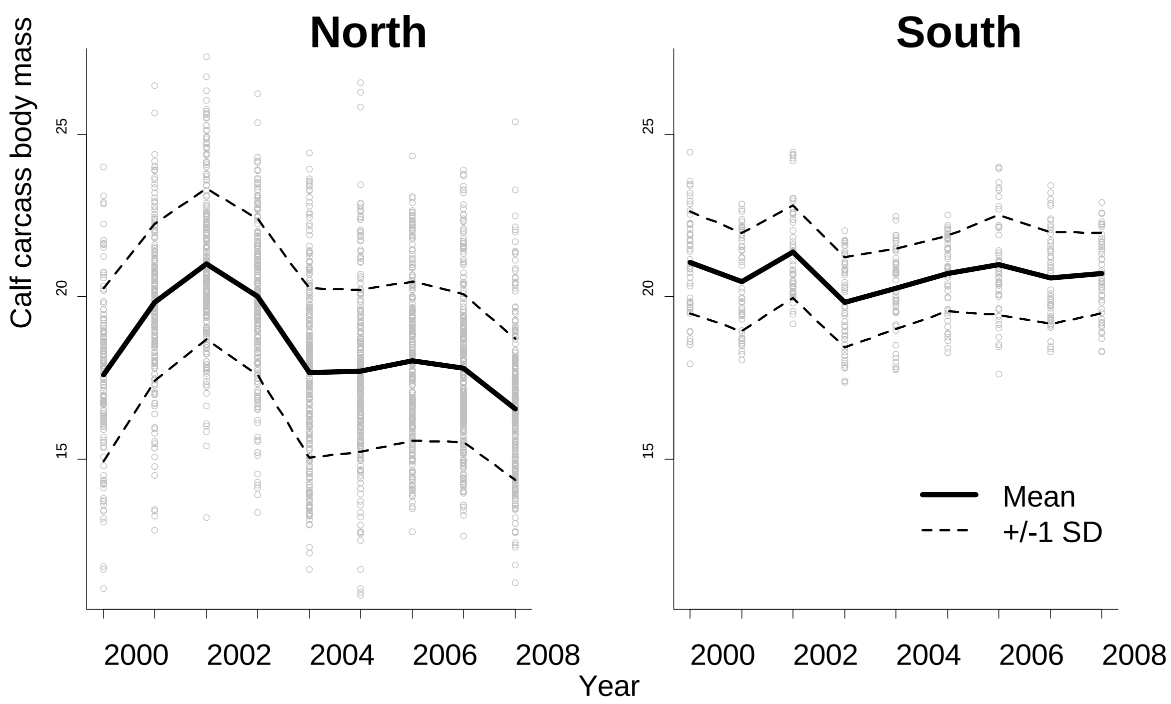
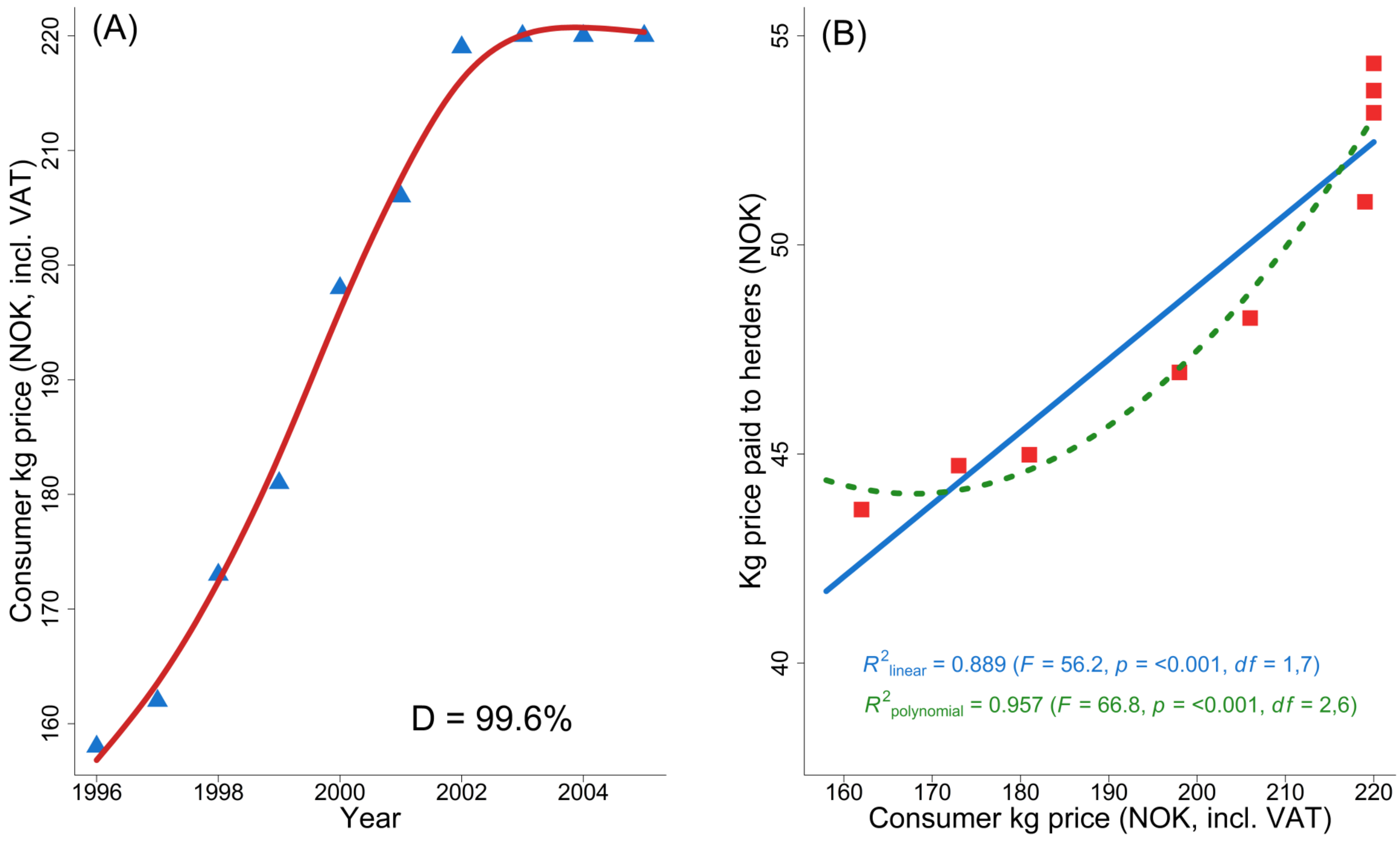


Figure 5. Temporal trends in calf body mass for the North (left) and South (right). Points show individual data while solid line show the average and hatched lines ± 1 SD. A linear regression model relating calf carcass body mass to region and year shows that calf carcass body mass is significantly lower in the North than in the South, an effect that is exacerbated over time (Table S4.1 provides details).

Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.



Næss, M. W. & Bårdsen, B.-J. (2015). Market economy vs. risk management: how do nomadic pastoralists respond to increasing meat prices? Human Ecology. 43(3):425-438. http://dx.doi.org/10.1007/s10745-015-9758-9.

Figure 6. Exploring other price measures. (A) The temporal trend in average consumer kg price (inclusive VAT) for reindeer meat in Norway. The line shows predictions from a Generalized Additive Model (GAM fitted using the mgcv-package developed by Wood 2012) with cubic regression splines, the amount of smoothing not fixed and where cross-validation was used to estimate the optimal amount of smoothing [GAM results: Intercept = 195.7 (SE = 0.7094, $p < 0.001$); effective degrees of freedom (year) = 4.147 ($p < 0.001$)]. (B) The relationship between consumer kg price (inclusive VAT) and price paid by slaughterhouses to reindeer herders for Norway as a whole. Note: data pertaining to consumer kg price is only available for 1997-2005. After 2005 consumer price is not included in the publications from the Norwegian Agriculture Agency. Please also note that the consumer price is an estimate based on different quality of reindeer meat than price paid to herders, i.e. price paid to herders is an average for all types of meat while consumer price is based on the best quality meat (Anonymous 2005b:81). Source: data points for consumer price extracted from figures in Anonymous (2001:fig. 6.5.3, 2005b:fig. 6.6.2).

S1 – MODEL SELECTION

We followed the protocol developed by Zuur et al. (2009) for model selection in the present study. Selecting the models used for inference in each of the steps described above was performed using *Akaike's Information Criterion* (AIC) (Anderson 2008, Burnham and Anderson 2002, Zuur *et al.* 2009). For each of the steps above we rescaled and ranked models relative to the model with the lowest AIC value (Δ_i denotes this difference for model *i*), and we selected model with the lowest Δ_i. First we plotted the residuals from a regular linear regression fitted to our data against the grouping factors district ($ID_{district}$) and siida-share (ID_{id}) to identify possible grouping effects that had to be taken into account. In short, the plots revealed that both districts and siida-shares were important grouping factors. In line with previous studies we thus decided to investigate whether districts, siida-shares and siida-shares nested within districts should be included as random intercepts in our model (e.g. Næss and Bårdsen 2010, Næss *et al.* 2010, Næss *et al.* 2011, Næss *et al.* 2012, Næss *et al.* 2009).

Random effects

Following Zuur et al. (2009) we utilized model selection with regard to the random effect structure started with a model containing the most complicated fixed effect structure, i.e. the most complex model, that we had *a priori* expectations to (see main text for specification). To formally assess the appropriateness of a random effects model, we fitted a regular linear regression model without random effects using the *gls* function and compared it to the random effects models fitted with the *lme* function (both are found within the nlme-package: Pinheiro *et al.* 2014) for R (R Core Team 2014). We also used standard modelling diagnostics plots in order to assess if the selected models fulfilled the underlying assumptions for these models (e.g. Zuur *et al.* 2010). Both likelihood ratio testing (not shown) and AIC values indicated that a mixed effect model was more parsimonious compared to its regular linear model counterpart (Table S1.1).

Visual inspection of the selected model from Table S1.1 indicated a possible problem related to heterogeneity, i.e. the variance seemed to decrease for higher values of $Kg\ price$ (Figure S1.1). As a consequence, we refitted the model with different variance structures using $Kg\ price$ as the variance covariate (Zuur *et al.* 2009).

Four different variance structures were investigated, where we selected a model and used for inference based on differences in AIC values (as suggested by Zuur *et al.* 2009:84). We utilized: (1) a fixed variance function that allows for larger residuals as $Kg\ price$ increases (*varFixed*); (2) an exponential variance structure where the variance of the residuals were determined as an exponential function of $Kg\ price$ ($varExp_1$); (3) same as 2 allowing for the exponential function to vary according to *Region* ($varExp_2$); and (4) a combination of variance structures where *Region* was modelled with a fixed variance structure and $Kg\ price$ with exponential variance structure common for both regions (*varComb*: Table S1.2). Visual inspection of the winning model in Table S1.2 indicated that changing the variance structure removed the previous problem related to heterogeneity (Figure S1.2). Visual inspection indicated that one observation could be considered as an outlier and was thus removed (Figure S1.2). The exclusion of the observation had no impact on the significance or direction of the parameter estimates in the presented model (although some estimates changed negligible) and thus the inclusion or exclusion of the observation did not affect the inferences presented.

Fixed effects

As stated in the main text, we only selected between models that differed with the respect of two three-way interactions using differences in AIC variables ($N \times Kg\ price \times Region$ & $Kg\ price \times Calf\ body\ mass \times Region$). This was also done following the procedure by Zuur et al. (2009). All other predictors were kept in all candidate models based on our *a priori* expectations (see main text for details). The selected model used for inference, were the one where the two three-way interactions were kept in the model (Table S1.3).

Tables

Table S1.1. The relative evidence for each candidate random effects model (REM) based on differences in AIC values (Δ_{AIC}). The **underlined model in bold** was selected and used for further analyses. To compare REMs with the regular linear model (RLM), mixed effects models were fitted with restricted maximum likelihood (REML). Note: mixed effects models included random intercepts only.

Model	***df***	Δ_{AIC}
RLM		
gls	13	1180.2
REMs		
$ID_{district}$	14	357.3
ID_{id}	14	164.2
ID_{id} in $ID_{district}$	**15**	**0.0**

Table S1.2. The relative evidence for each candidate model with different variance structures based on differences in AIC values (Δ_{AIC}). The **underlined model in bold** was selected and used for inference (Table 2 in main text).

Model	***df***	Δ_{AIC}
Random effects only[a]		
ID_{id} in $\mathrm{ID}_{\mathrm{district}}$	15	573.8
Different variance structures		
varFixed	15	677.7
$varExp_1$	16	511.3
$varExp_2$	17	76.1
varComb	**17**	**0.0**

[a] The selected model from Table S1.1.

Table S1.3. The relative evidence for each candidate fixed effects model based on differences in AIC values (Δ_{AIC}). The **underlined model in bold** was selected and used for further analyses. Maximum likelihood (ML) fitted models were used when these models were compared (Pinheiro and Bates 2000). Predictors in **bold** were kept in all models based on *a priori expectations* (see main text for details).

i	***N***	***Kg price***	***Calf body mass***	***Region***	***N × Kg price***	***Kg price × Calf body mass***	***Kg price × Region***	***Calf body mass × Region***	***N × Region***	*N × Kg price × Region*	*Kg price × Calf body mass × Region*	*df*	Δ_{AIC}
1	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**17**	**0.0**
2	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**		x	16	8.0
3	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	x		16	13.1
4	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**			15	24.2

Figures

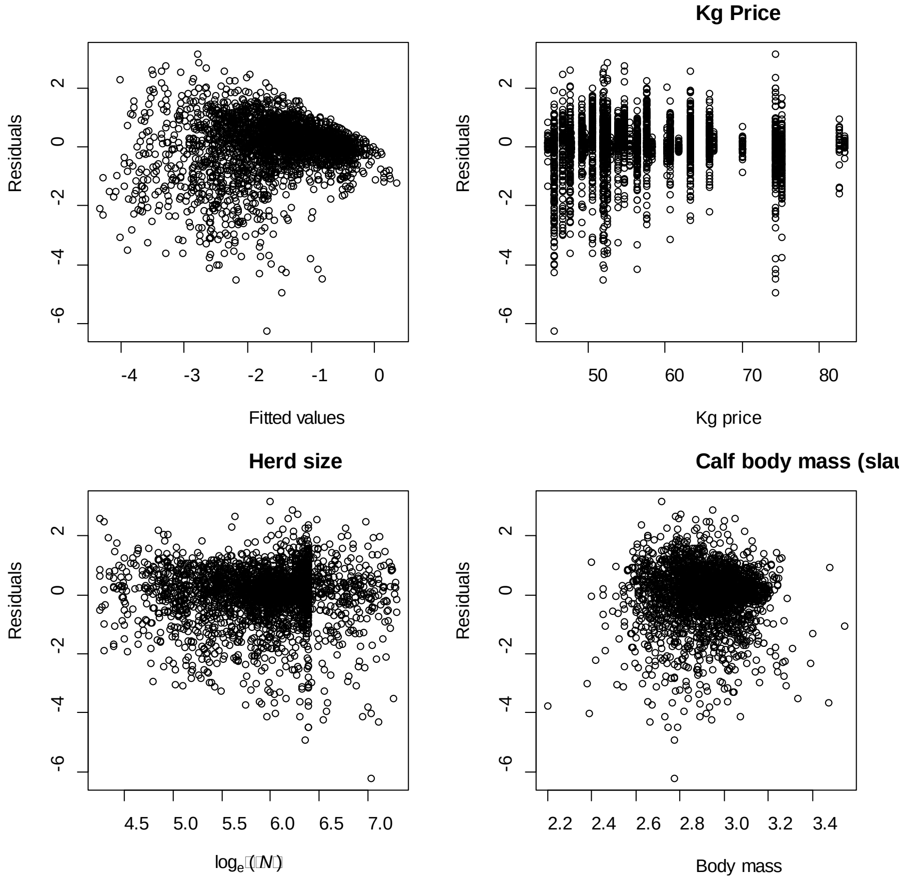


Figure S1.1. Visual model validation of the model with the selected random structure from Table S1.1. *Top left*: Fitted values plotted against residuals. *Top right*: *Kg price* plotted against model residuals. *Bottom left*: *N* (herd size) plotted against model residuals. *Bottom right*: *Calf body mass* plotted against the model's standardized residuals. The clearest residual trend seems to be related to *Kg price*, i.e. as *Kg price* increases, variance decreases.

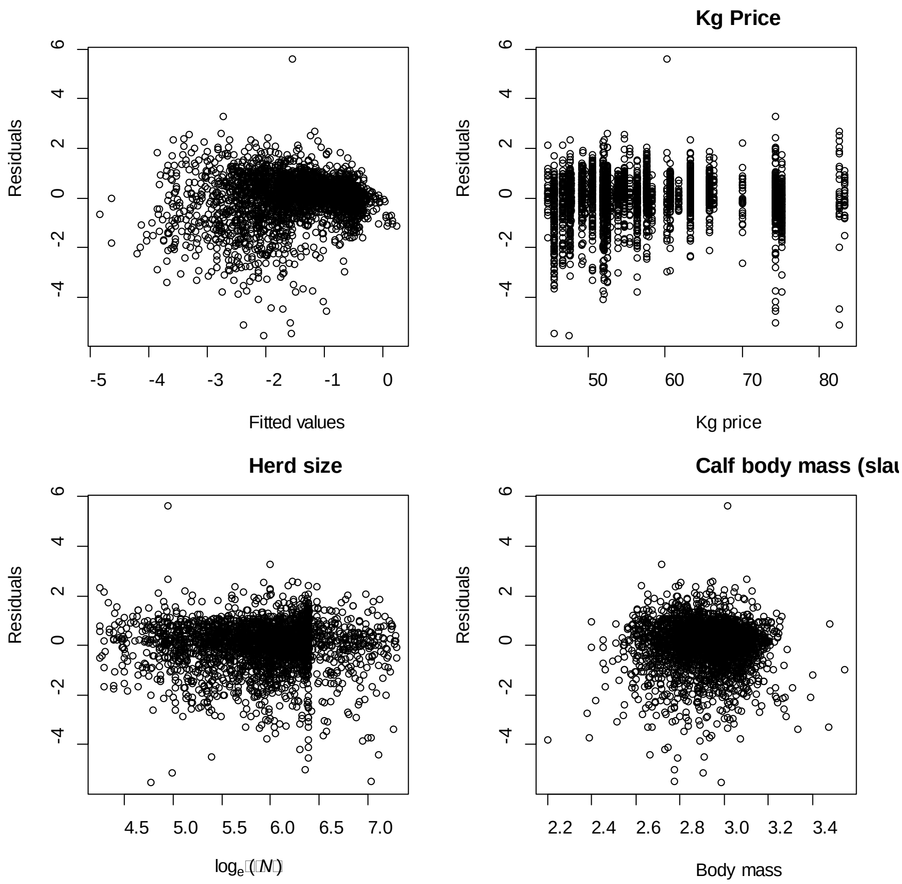


Figure S1.2. Visual model validation of the model with the selected variance structure from Table S1.2. *Top left*: Fitted values plotted against residuals. *Top right*: *Kg price* plotted against model residuals. *Bottom left*: *N* (herd size) plotted against model residuals. *Bottom right*: *Calf body mass* plotted against models' standardized| residuals. The previous problem related to heterogeneity in relation to *Kg price* has now been removed although one observation seems be an outlier.

References cited

R Core Team. (2014). R: A language and environment for statistical computing.

Anderson, D. R. (2008). Model based inference in the life sciences: a primer on evidence, Springer Science, New York, United States of America.

Burnham, K. P., and Anderson, D. R. (2002). Model selection and multimodel inference: a practical information-theoretic approach, Springer, Inc., New York, USA.

Næss, M. W., and Bårdsen, B.-J. (2010). Environmental Stochasticity and Long-Term Livestock Viability-Herd-Accumulation as a Risk Reducing Strategy. Human Ecology 38(1):3-17.

Næss, M. W., Bårdsen, B.-J., Fauchald, P., and Tveraa, T. (2010). Cooperative pastoral production - the importance of kinship. Evolution and Human Behavior 31(4):246-258.

Næss, M. W., Bårdsen, B.-J., Pedersen, E., and Tveraa, T. (2011). Pastoral herding strategies and governmental management objectives: predation compensation as a risk buffering strategy in the Saami reindeer husbandry. Human Ecology 39(4):489-508.

Næss, M. W., Bårdsen, B.-J., and Tveraa, T. (2012). Wealth-dependent and interdependent strategies in the Saami reindeer husbandry, Norway. Evolution and Human Behavior 33(6):696-707.

Næss, M. W., Fauchald, P., and Tveraa, T. (2009). Scale Dependency and the "Marginal" Value of Labor. Human Ecology 37(2):193-211.

Pinheiro, J. C., and Bates, D. M. (2000). Mixed-effects models in S and S-PLUS. Statistics and computing, Springer, New York.

Pinheiro, J. C., Bates, D. M., DebRoy, S., Deepayan, S., and R Core Team. (2014) nlme: Linear and Nonlinear Mixed Effects Models. R package version 3.1-117,

Zuur, A. F., Ieno, E. N., and Elphick, C. S. (2010). A protocol for data exploration to avoid common statistical problems. Methods in Ecology & Evolution 1(1):3-14.

Zuur, A. F., Ieno, E. N., Walker, N., Saveliev, A. A., and Smith, G. M. (2009). Mixed effects models and extensions in ecology with R, Springer-Verlag New York, New York, NY.

S2 - DATA EXPLORATION, VARIABLE TRANSFORMATIONS & MULTICOLINEARITY

DATA EXPLORATION & VARIABLE TRANSFORMATION

As stated in the main text, we selected siida-shares that had >70 & ≤ 1500 reindeer. Moreover, we also selected summer districts that contained more than 2 siida-shares. Possible predictors initially considered was: (1) herd size; (2) number of slaughtered calves; (3) number of marked calves; (4) calf body mass (slaughtered); and (5) year. Visual inspection when plotting these continuous variables indicated the presence of possible outliers. Following Zuur et al. (2009) we transformed the variables using the natural logarithm, a procedure that as far as we can judge removed these problems.

MULTICOLINEARITY

Following Zuur et al. (2010, 2009) we also investigated possible problems in relation to multicolinearity among possible predictors (since any large values will tend to dominate correlation coefficients between variables involving them, the following procedures was done on the transformed variables, as suggested by Zuur *et al.* 2009:534).

High, or even moderate, collinearity is problematic when effects are weak as it may cause non-significant parameter estimates (i.e., the precision of the estimates decrease, see Licht 1995), compared to a situation without collinearity. With collinearity problems removed, variables may become significant, indicating that problems pertaining to collinearity may render significant terms non-significant (Zuur *et al.* 2010). More to the point, if collinearity is ignored it is possible to end up with a statistical analysis where nothing is significant, but where dropping one predictor may make others significant, or even change the sign of estimated parameters (Zuur *et al.* 2010).

Possible colinearity problems were investigated by looking at the variance inflation factor (VIF) between the variables utilizing the *corvif* function in the file *HighstatLib.R* in Appendix S1 in Zuur *et al.* (2010; URL: http://onlinelibrary.wiley.com/doi/10.1111/j.2041-210X.2009.00001.x/suppinfo). VIF represents the proportion of variance in one predictor explained by all the other predictors in the model where the lower the VIF the better (i.e. a VIF = 1 indicates no collinearity, whereas increasingly higher values suggest increasing multicollinearity Zuur *et al.* 2010).

The approach utilized in this study was to sequentially drop the covariate with the highest VIF, recalculate the VIFs and repeating this process until all VIFs were smaller than 5 (suggestions range from 10-1, see Zuur *et al.* 2010). An important caveat should be noted: we dropped possible predictors that we had less theoretical interest in estimating first, even though a variable with more theoretical interest might have had a higher or similar VIF value (Table S2.1-2.3).

Table S2.1. Variance inflation factors (VIF) for all possible predictors to be estimated.

Variables	VIF
Calf slaughter‡ (response)	4.67
Slauhtered calves‡ (predictor)	6.39
N‡ (predictor)	5.89
Kg price‡ (predictor)	5.28
Marked calves‡ (predictor)	7.27
Calf body mass‡ (predictor)	1.27

Year (predictor)	5.65
Region (predictor)	1.38

‡log$_e$-transformed.

Table S2.2. Variance inflation factors when removing predictors that the response was constructed from (*Slaughtered calves* & *Marked calves*).

Variables	VIF
Calf slaughter‡ (response)	1.32
N‡ (predictor)	1.11
Kg price‡ (predictor)	5.27
Calf body mass‡ (predictor)	1.25
Year (predictor)	5.59
Region (predictor)	1.35

‡log$_e$-transformed.

Table S2.3. Variance inflation factors when also removing *year*. Year was chosen since we had an *a priori* theoretical interest in estimating the effect of *Kg price* (see main text for details).

Variables	VIF
Calf slaughter‡ (response)	1.31
N‡ (predictor)	1.10
Kg price‡ (predictor)	1.12
Calf body mass‡ (predictor)	1.19
Region (predictor)	1.29

‡log$_e$-transformed.

References cited

Licht, M. H. (1995). Multiple Regression and Correlation. In L. G. Grimm and P. R. Yarnold (eds.), Reading and understanding multivariate statistics, American Psychological Association, Washington, D.C., pp. 19-64.

Zuur, A. F., Ieno, E. N., and Elphick, C. S. (2010). A protocol for data exploration to avoid common statistical problems. Methods in Ecology & Evolution 1(1):3-14.

Zuur, A. F., Ieno, E. N., Walker, N., Saveliev, A. A., and Smith, G. M. (2009). Mixed effects models and extensions in ecology with R, Springer-Verlag New York, New York, NY.

S3 – PROBING THE INTERACTIONS TO UNDERSTAND THEM

To get a greater understanding of the interactions in Table 1, main text, we followed Aiken and West (1991) suggestion to recast the regression equation as the regression of the response on one predictor. For illustration, this is done by transforming a general linear equation on the form:

$$Y = b_0 + b_1 X_1 + b_2 X_2 + b_3 X_1 X_2$$

To:

$$Y = (b_1 + b_3 X_2) X_1 + (b_2 X_2 + b_0)$$

The slope of the regression of Y on X_1, $(b_1 + b_3 X_2)$, depends upon the particular value of X_2 at which the slope is considered. We refer to $(b_1 + b_3 X_2)$ as the simple slope of the regression of Y on X_1 at X_2. By simple slope we mean the slope of the regression of Y on X_1 at (conditional on) a single value of X_2. In other words, the simple slope $(b_1 + b_3 X_2)$ combines the regression coefficient of Y on X_1 (b_1) with the interaction coefficient (b_3) (Aiken and West 1991:12).

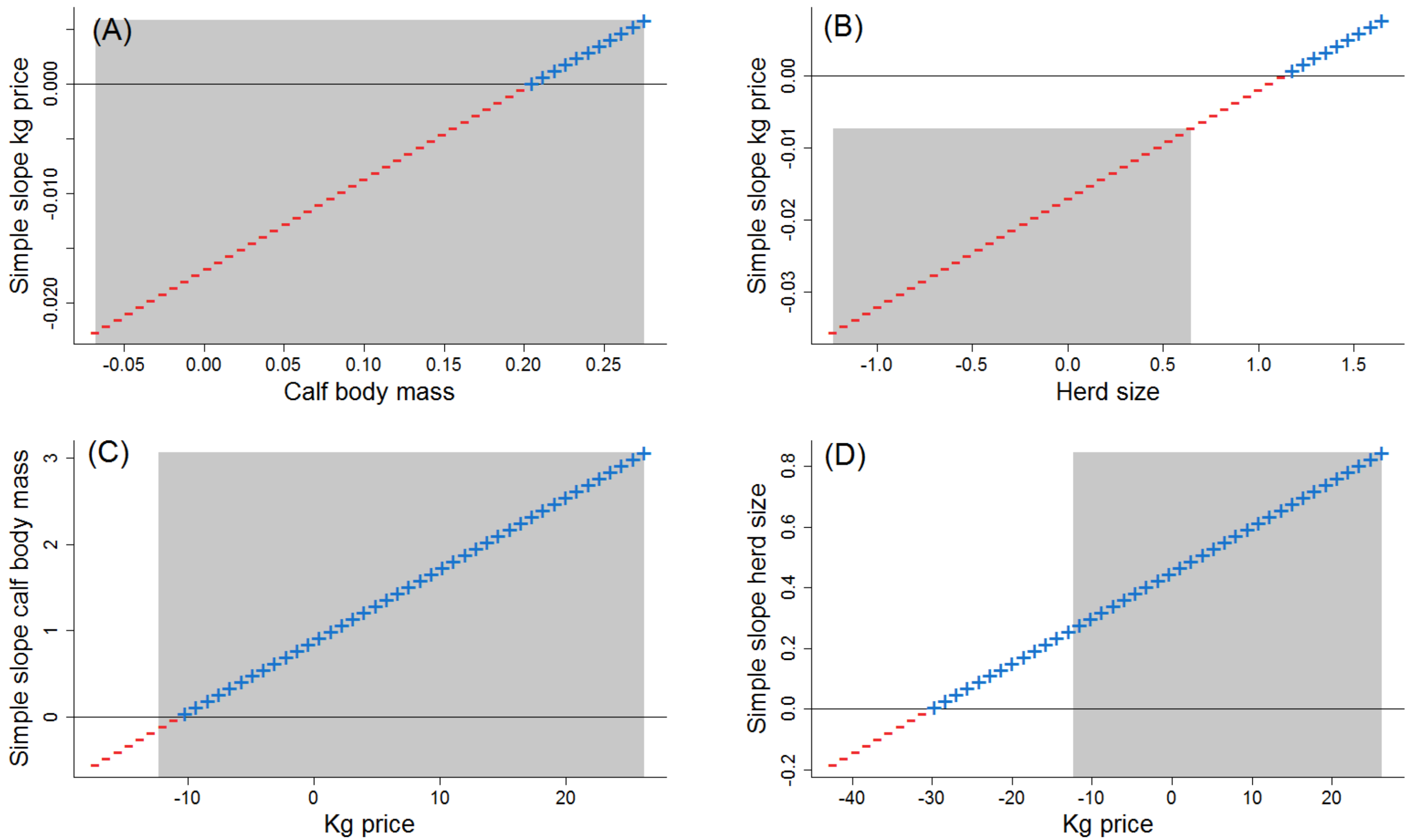


Fig. S3.1. Showing the simple slopes from the analyses presented in Table 2 main text for the southern region. (A) The slope of *Kg price* conditional on values of *Calf body mass*; (B) The slope of *Kg price* conditional on values of *N* (herd size); (C) The slope of *Calf body mass* conditional on values of $Kg\ price$; and (D) The slope of N (herd size) conditional on values of $Kg\ price$. Grey shaded areas indicate range of data, i.e. regions outside of the grey area is shown only to visualize where the simple slopes changes direction.

References cited

Aiken, L. S., and West, S. G. (1991). Multiple regression: testing and interpreting interactions, Sage, Newbury Park, Calif.

S4 – Calf carcass body mass, temporal trends in price and slaughter

Tables

Table S4.1. Estimates from a linear model relating Calf carcass body mass to Region and Year. See main text for discussion.

	Response: Calf carcass body mass			
Parameter	Estimate	SE	*t*	*P*
Intercept	20.659	0.116	178.2	<0.001
Region (North)	-2.199	0.127	-17.3	<0.001
Year	-0.017	0.045	-0.4	0.711
Region (North) × Year	-0.355	0.049	-7.2	<0.001
($F = 212.7$; $df = 3, 2727$; $P < 0.001$; $R^2 = 0.19$)				

Figures

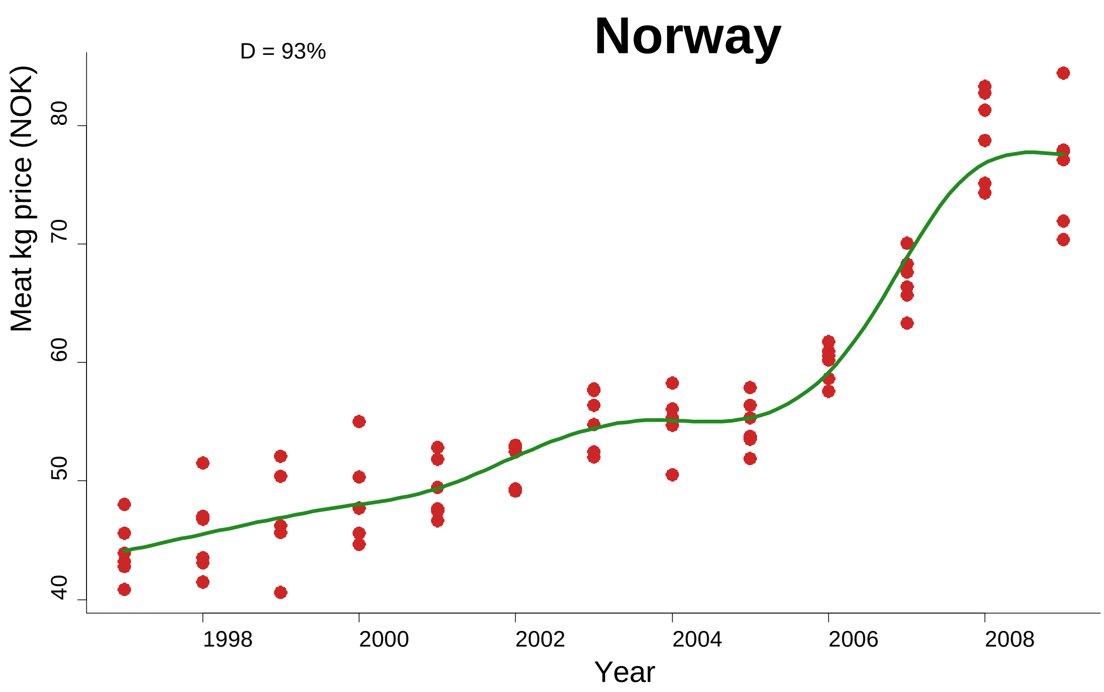


Figure S4.1. Temporal trends in average price per kg for reindeer meat for six reindeer husbandry areas in Norway (East- and West-Finnmark, Troms, Nordland, North-Trøndelag and South-Trøndelag/Hedmark). The line shows predictions from a Generalized Additive Model (GAM, fitted using the mgcv-package in R developed by Wood 2012) with cubic regression splines, the amount of smoothing not fixed and where cross-validation was used to estimate the optimal amount of smoothing [GAM results: Intercept = 56.41 (SE = 0.3605, $p < 0.001$); effective degrees of freedom (year) = 7.555 ($p < 0.001$)]. Source: Anonymous (2001, 2004, 2008, 2010).

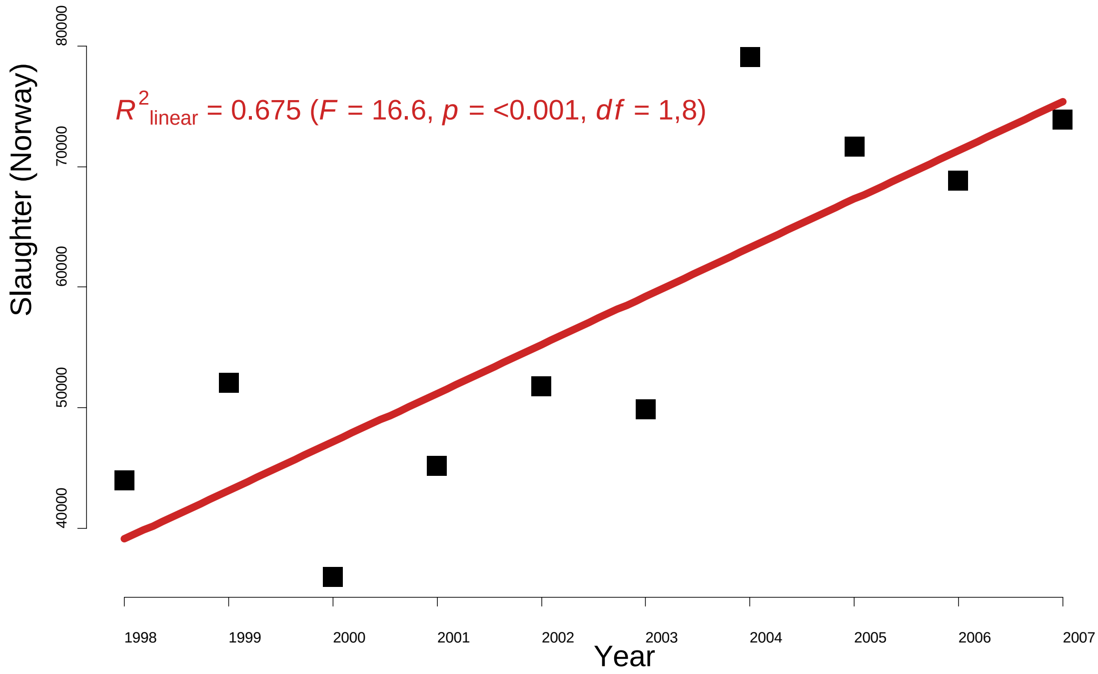


Figure S4.2. Temporal trends in total amount of slaughter for the reindeer husbandry in Norway. Linear trend suggest that slaughter has increased during the period and show no apparent increase in slaughter prior to the collapse (i.e. 2001) designated in Næss and Bårdsen (2013). In other words, the national trend do not seem to indicate that herders converted their livestock wealth into other capital prior to the collapse to offset some of the negative impacts of the environmental induced losses (in line with evidence from other parts of the world, see section 'Differential value of pastoral products – pastoralists and the market' in main text for details). Please note that this figure represent aggregated data, while the analyses presented in the main text are based on siida share data from 2000 to 2008. Source: (Anonymous 2001: table 4.1.4, Anonymous 2004:table 4.1.2, Anonymous 2009:table 4.1.2).

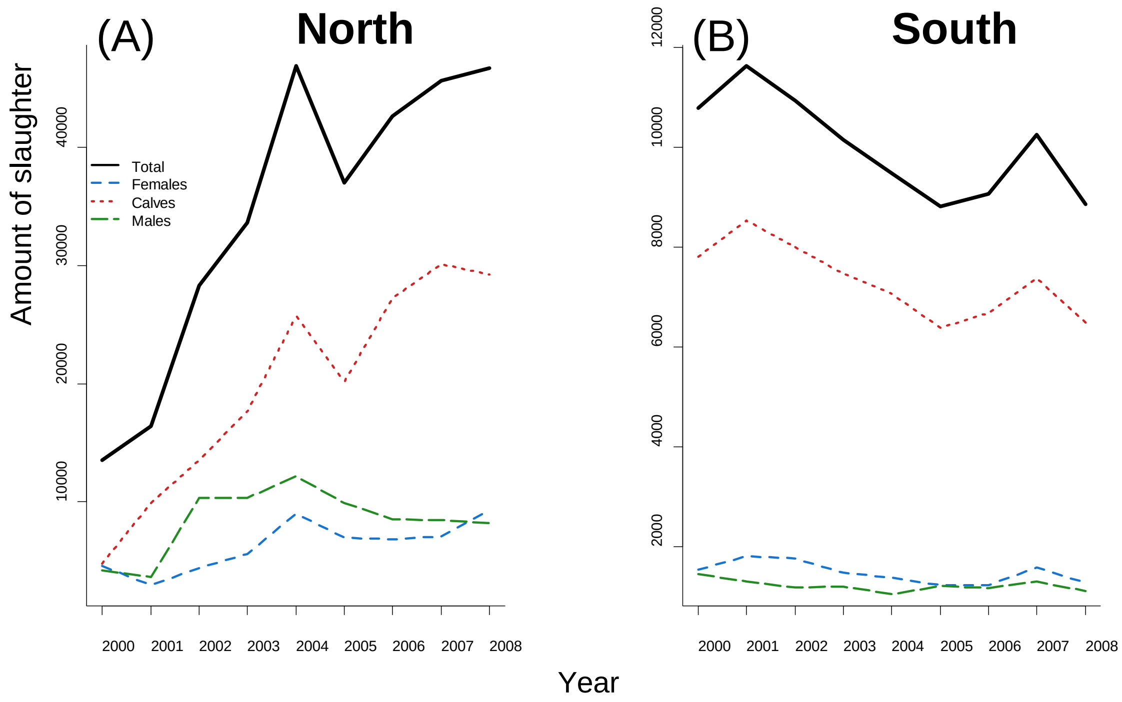


Figure S4.3. Temporal trends in amount of slaughter undertaken in (A) the north and (B) the south.

References cited

Anonymous. (2001). Totalregnskap for reindriftsnæringen. Reindriftsforvaltningen, Alta, Norway, pp. p. 145.

—. (2004). Totalregnskap for reindriftsnæringen. Reindriftsforvaltningen, Alta, Norway, pp. p. 143.

—. (2008). Totalregnskap for reindriftsnæringen. Reindriftsforvaltningen, Alta, Norway, pp. p. 126.

—. (2009). Totalregnskap for reindriftsnæringen. Reindriftsforvaltningen, Alta, Norway, pp. p. 126.

—. (2010). Totalregnskap for reindriftsnæringen. Reindriftsforvaltningen, Alta, Norway, pp. p. 132.

Næss, M. W., and Bårdsen, B.-J. (2013). Why Herd Size Matters – Mitigating the Effects of Livestock Crashes. Plos One 8(8): e70161.

Wood, S. N. (2012) mgcv: GAMs with GCV/AIC/REML smoothness estimation and GAMMs by PQL. R package version 1.8.0.