Title:

Comparison of social complexity in two independent pastoralist societies

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This is a post-peer-review, pre-copyedit version of an article published in Behavioral Ecology and Sociobiology. The final authenticated version is available online at: http://dx.doi.org/ 10.1007/s00265-018-2611-6.

Abstract

Pastoralists rely on networks of cooperating households containing relatives and others to help with production and various other daily activities. To understand how socioecological differences and commonalities affect different social networks, we compared cooperative decision-making using gift games for 755 people working in herding groups across six sites in two countries (Saami areas in Norway and Tibetan areas in China). We found that members of the same herding group received more gifts from each other. Most variance in gift-giving between study sites was due to differences in the effects of relatedness. Tibetan herders were more likely than Saami herders to give gifts to closer relatives belonging to geographically distant herding groups. Also, stated reasons of giving gifts were different in the two societies: kin and wealth (measured by herd size) were more important among Tibetan pastoralists, while reciprocity was more important among Saami. Social ties within and beyond the family as well as the centrality of herding groups within social networks are general patterns of social organization favoring cooperation among pastoralists.

Significant statement

Pastoralists around the world have independently developed social institutions built around cooperative herding units, known as *siidas* in Norway and *ru skor* in China. Our study investigates how kin and non-kin, in the same herding group or belonging to other groups, as well as wealth (measured by herd size) are associated with cooperation. Our results show that communities in both countries exhibit similar social patternin terms of who they chose to give gifts to, despite differences in socioeconomic status and culture. Most of the variance in cooperation occurred between sites, primarily due to the effect of kinship. Members of the same herding group were preferred recipients of gifts, regardless of kinship, although closer kin were more likely to receive gifts. The stated reasons for giving were different in the two sites: *siidas* prioritized reciprocity whereas *ru skor* preferred kin and less wealthy herders.

Keywords:

Evolution of cooperation; social networks; field experiment; social institutions

Introduction

Empirical studies of social evolution in humans have shown how cooperative interactions among kin of varying degree, as well as non-kin, are shaped in part by social and ecological contexts (Henrich et al. 2005; Ruffle and Sosis 2006; Cronk 2007; Herrmann et al. 2008; Buchan et al. 2009; Lamba and Mace 2011; Prediger et al. 2011; Apicella et al. 2012; Balliet and Lange 2013; Gerkey 2013; Leibbrandt et al. 2013; Silva and Mace 2014; Wu et al. 2015; Smith et al. 2016; Thomas et al. 2018). Previous studies have found more between-group than within-group variability in cooperativeness, where 'groups' can refer to societies in different countries (Henrich et al. 2005), ethnic groups in the same country (Wu et al. 2015), or villages and camps within a single ethnic group (Lamba and Mace 2011; Apicella et al. 2012). Researchers disagree about the extent to which this variation is driven by differences in market integration and stable society-wide cultural norms (Henrich et al. 2005), or more localized differences in demography (Lamba and Mace 2011, Smith et al 2016) and/or different expectations of trust and fairness (Gurven et al. 2008).

Assortment is fundamental for cooperation to evolve, and social networks are shaped by individuals clustering on a number of dimensions, including reciprocal benefits, shared genes, reputations, need, economic condition, or the 'market value' of potential social partners (Nowak and May 1992; Fletcher and Doebeli 2009; Allen et al. 2017). Disruptions to socioecological systems can have unforetold consequences on social networks, especially for smaller-scale societies whose members rely on flexible cooperative interactions with others to survive and thrive: a pertinent example being pastoralists. Pastoralists often find themselves socially marginalized in nation states and tend to inhabit arid or marginalized areas not well-suited to farming. Many herders are experiencing challenges due to climate change, pasture fragmentation, changes in land tenure, globalization, and threats to their way of life. Although strategies of subsisting on herd animals have existed in various forms for thousands of years (Honeychurch and Makarewicz 2016) little is known about the patterns and processes of contemporary pastoralist cooperation in different socioecological contexts.

Pastoralists around the world tend to organize their labor in cooperative herding groups (Næss 2012). These groups are typically formed of several related households, allowing herders to pool risk, achieve economies of scale, and survive in otherwise uncertain environments, while also facilitating communication, monitoring and sanctioning (Mace 1998; Næss et al. 2010; Aktipis et al. 2011; Næss 2012). Within their social networks, pastoralists rely on herding groups whose members are made up of kin and non-kin (Thomas et al. 2015); these groups often include close kin, suggesting a role for inclusive fitness benefits, possibly as a byproduct of assortment regardless of direct cooperative interactions. Pastoralist groups in eastern Africa have developed norms allowing those in need to freely borrow livestock from herding partners with a surplus of animals, without obligations to repay (Cronk 2007); others leverage their friendship networks to recruit raiding partners (Glowacki et al. 2016).

Saami herders in Norway and herders on the Qinghai-Tibetan Plateau (QTP) in China utilize similar social institutions: cooperative groups—called *siida* in the Saami languages (Paine 1994) and *ru skor* among Tibetan herders QTP (Nietupski 2012)—that collaborate on herding tasks and share pastures at certain times of year. In Norway, a *siida* consists of one or more license owners and is a cooperative herding group, traditionally consisting of several related families (although kinship is not a necessary criterion for membership). *Siidas* are grouped into districts: formal administration units defined by the government (Thomas et al. 2016). In China, members of the same *ru skor* are often related because brothers who establish new households tend to stay in the same group. Several *ru skor* will form a production group (called *sheng chan dui* in Chinese (Yamaguchi 2011)), usually below the village level, but herding and daily life activities are mostly clustered within *ru skor*.

Pastoralism in Saami areas of Norway and on the QTP varies greatly in scale and extent. Reindeer herding encompasses approximately 120,000 km^2 (> 40% of mainland Norway), with a little over 3,000 herders owning ~250,000 reindeer (Anonymous 2016). There are around 5 million Tibetan herders owning 12 million yaks and 30 million goats and sheep, with over 1.6 million km^2 of rangelands (~64% of QTP in China; see (Næss 2016) and SI Text).

Organization of winter pastures in Finnmark, Norway, shifted in the late 1970s from a customary land tenure system to a common system; today, winter pastures are in the process of becoming privatized or semi-privatized. Following the Reindeer Husbandry Law of 1933, reindeer herding in Finnmark was formally (and

physically) separated into different summer districts: pasture areas that can consist of several summer *siidas*, bounded by fences. In contrast, winter pastures are currently being reorganized primarily through establishing fixed winter *siida* grazing boundaries and user rules (Næss 2017). Rangelands on the QTP were leased to households starting in the early 1990s, based on the number of inhabitants and are enclosed by fences. By the end of 2003 around 70% of China's usable rangeland was leased through long-term contracts, where 68% was contracted to individual households and the rest to groups of households or to villages, although estimates vary (Næss 2013). In the study area, winter pastures were first contracted to individual households whereas the summer pastures were contracted to a maximum of three households (Cao et al. 2013). There are also households grazing separately from others, both in winter and summer areas; the preference for herding alone rather than in groups has been increasing since privatization was introduced.

To investigate variation in cooperative herding behavior within and between the two countries, we analyzed cooperative behavior from individual herders working in herding groups within six study sites. Our data encompasses 212 reindeer herders in 33 *siidas* across summer and winter districts within two zones in Finnmark, northern Norway and 1,192 yak herders from 172 *ru skors* in four villages in Maqu county, in the eastern part of QTP, China. Henceforth, we will refer to these districts in Norway and villages in China as our 'study sites' (or 'sites'). We employed a gift allocation task to reveal the structure of existing social relationships, similar to those used in studies of groups of hunter-gatherers (Apicella et al. 2012; Thompson et al. 2015) and pastoralists (Thomas et al. 2015; Glowacki et al. 2016). In these gift games, participants anonymously distributed gifts to at least one other person (see Methods).

Studies to date have not analyzed cross-cultural variation in cooperation among populations following similar subsistence strategies and social organization, but where there are differences in country-level social, political and ecological contexts. To address this gap, we examine variation in cooperative behavior within and between groups of pastoralists living in Norway and China. The main aim of this study is to understand cross-cultural variation in cooperation among herders in Norway and China as well as the causes of variation by investigating patterns of gift giving. Since previous studies found that herders gave gifts to social partners who were members of their own herding group and/or relatives (Thomas et al. 2015), we expect that, across all sites, members of the same herding group will be preferentially chosen as gift recipients, especially when those members are relatives. Nevertheless, considering the differences in pasture organization, we expect that the spatial constraints and shared borders in Finnmark necessitate higher levels of between-group cooperation and coordination to ameliorate issues such as mixing of herds, compared to the situation on QTP. Moreover, due to the individualized pasture situation on the QTP, we expect that kinship is a more important determinant for gift giving than group membership compared to Finnmark. In addition, previous studies have also found that herders gave gifts to people reputed to be high-quality partners, young people new to the lifestyle (Thomas et al. 2015), or people who were high status in terms of wealth and leadership (Glowacki et al. 2016) or other social skills (Smith et al. 2017). Consequently, we also explore the similarities and differences in terms of stated reasons of gift-giving between sites as well as how herding success, measured as herd size (Næss 2010), influences gift giving between sites.

Methods

MGT conducted fieldwork in Karasjok, Norway, in July and August 2013 and in Kautokeino, Norway, in June-August 2016, employing local assistants to aid in interviews and translation. Participants were adult reindeer herders of any gender. JD conducted research in QTP, China, in July-October 2016, employing three local assistants to help in translation and field work. In each site, we asked adult male and female herders to play economic games following a demographic questionnaire. Kinship networks were created in slightly different ways in the different sites: see SI for details.

Gift games

Participants were endowed with a fixed gift and were asked to give everything away to at least one other person; they were not allowed to keep anything for themselves. Herders in QTP and Karasjok, Finnmark, could give their gifts to a maximum of three people; there was no limit in Kautokeino, but the median number of gifts given away was two (the maximum given by any one herder was 7 gifts). In Finnmark,

participants could only give gifts to licensed herders within their district (*siidaandeler;* in English meaning *siida*-share*,* or effectively heads of households). In China, participants could give to anybody in the same site, except people in their own household. See SI Text for further discussion.

Participants in Norway were presented with a list of names of license owners in their district, with associated anonymous ID numbers; the ID numbers of their chosen recipients were recorded. In China, we asked participants to name any members of the same site that they wish to give gifts to; we also asked for the recipients' other information, e.g. name of his/her family head etc., to avoid any mistakes, as locals are likely to share the same name.

Participants in China were endowed with 15 yuan ($4.33 purchasing power parity [PPP] in July 2015); herders in Karasjok, Norway, were given vouchers representing 15 liters of petrol (225 Norwegian kroner; $24.92 PPP in July 2013); herders in Kautokeino, Norway, were endowed with 35 liters in petrol vouchers (525 NOK; $52.34 PPP in July 2016). PPP amounts were calculated from the OECD's indicators for the relevant years and countries (OECD 2017); see Table S1. In addition to the game endowments, we also gave small gifts to each person as compensation for their participation: in China, we gave them sweets or laundry powder; in Norway participants in Kautokeino received 300 NOK and participants in Karasjok received 150 NOK. At the end of each field season in Norway and China, participants in Karajok and QTP were paid in cash, while those in Kautokeino were paid by bank transfer. Payments included participation fees. Gift game participants were also asked to report their reasons for giving gifts as an open-ended question.

An individual's position in their social network, as measured by indirect ties (e.g. friends of friends), has been associated with benefits including increased reproductive success (Brent 2015; Page et al. 2017). We quantified social network position in terms of individuals' betweenness and eigenvector centrality (Table S2); higher betweenness scores mean that an individual acts as a bridge or broker between otherwise unconnected people, while higher eigenvector centrality means that individuals are connected to other well-connected people (Brent 2015). We also estimated modularity—a measure of how a network can be partitioned into communities (Newman 2006; Fortunato 2010).

Statistical analyses

To analyze gift decisions, we fit Bayesian multilevel logistic regressions with varying intercepts for gift game participants nested within study sites. The predictors were: coefficient of relatedness; a binary variable representing whether or not a pair of herders (dyad) were membership of the same herding group; and an interaction between these two (see 'Model specification' section in Supplementary Information). This model structure allows us to estimate site-level effects as well as control for the non-independence of potential gift givers in dyads (Gelman et al. 2013; McElreath 2016); similar model structures have been used in previous studies employing gift games (Apicella et al. 2012; Thomas et al. 2015). A subset of models also included varying slopes for sites in order to estimate the different effects of relatedness and group membership between areas (Schielzeth and Forstmeier 2009; McElreath 2016) .

For the analysis of how herding success affects decisions to give gifts, we used herd size as an indicator of herding success; this has been used by other researchers as a reliable indicator of pastoralist production and family wealth (Roth 1996; Næss 2010). Since the most important source of income is from livestock, herding size is a reliable measure of herding success. Herd size was calculated from self-stated information or from government documents. We fitted Bayesian multilevel linear regressions with varying intercepts for study site to predict herd size z-scores (see Table S2 for specifications). Herd sizes were standardized to mean = 0 over 1 standard deviation, grouped within sites, to allow direct comparison across countries given the order of magnitude difference in livestock ownership (Fig. S5).

All models were run for 2,000 iterations, discarding the first half as warm-up. We fitted one chain for models of gift giving (due to the computational and temporal constraints of fitting such complex models to a large dataset) and four chains for the social network analysis. We checked that $\hat{R}$ scores (the potential scale reduction factor, measuring convergence of chains) were close to 1.0; they were in all cases.

For model selection in both regression analyses, we compared the approximate leave-one-out cross-validation information criteria (Vehtari et al. 2016)—an estimate of out-of-sample-predictive fit—and calculated model weights by stacking posterior predictive distributions (Yao et al.2017); in both cases, we selected the model carrying most weight for analyses presented here. All models were fitted in R 3.3 (R Core Team 2012) using the packages rstanarm (R Core Team 2012) and loo (Vehtari et al. 2016; Yao et al. 2017); social network statistics were calculated with iGraph (Csardi and Nepusz 2006). See SI Text for details of

model specifications.

Results

In total, 755 participants gave a total of 1,214 gifts (Table 1; note that the differences in sample size between countries are partly due to differences in population sizes and scale of the herding lifestyle, as well as different lengths of field seasons spent in each country). Models of the gift networks include only the gift game players as 'egos' (i.e. potential givers) but all the other members of the same site as 'alters', producing 219,112 within-site dyads. There were 28-60 winter herding groups in the four Tibetan sites, 24 winter herding groups in one Saami site and 9 summer herding groups in the other. The mean number of people in the Tibetan herding groups ranged from 3.98 (±1 standard deviation [SD] = 4.26) to 12.46 (SD=18.05), and in the Saami herding groups ranged from 5.71 (SD=3.33) to 8.33 (SD=4.72). There were no differences in mean group relatedness between the sites (Table 1).

Herders in Finnmark gave 74.1% of their 147 gifts to members of the same herding group, while herders in Tibet gave 40.6% of 1,067 gifts to members of the same group (Fig. S1). In Norway, the average amount received was $10.61 purchasing power parity (PPP); the maximum amount received by any one herder was $122.13 PPP. The average amount received in China was $2.38 PPP, with the maximum amount received being $33.18 PPP. Table S1 summarizes gifts by site.

Siidas and *ru skor* were composed of at least first cousins ($r \geq 0.125$) as well as non-kin (Fig. S2). In the Tibetan sites, approximately equal numbers of close kin (grandparents, parents, siblings and children; $r \geq 0.25$) belonged to other herding groups, whereas few close family members worked for other groups in Finnmark. Proportionally more gifts were given to non-kin on the QTP than to kin (range across the four sites: 61.5% – 70.5%) and in Karasjok, Finnmark (53.5%; Fig. S3).

The Kautokeino site in Finnmark appears to be different from Tibetan sites in terms of gift-giving behavior, with the majority of gifts (77.6%) going to relatives rather than non-kin. This may be in part due to the recognition of distantly related herders (*r* between 0.0078 and 0.0630; Fig. S2), which may have occurred because of different data collection techniques in this site (see SI Methods) or due to there being no upper limit on number of gift recipients (see Methods). However, the Kautokeino data focused specifically on cooperation in winter *siidas*, which tend to be smaller and more family-oriented groups (Paine 1994).

Across all study sites in both regions, relatedness and herding group co-membership positively predicted gift-giving, while the interaction term was negative (Fig. 1; Table S3 and Table S4). Taken together, the predicted probabilities of gift giving as relatedness and group membership co-vary reveal similarities and differences within and between countries (Fig. 2). Across sites, members of the same herding group were more likely to receive gifts compared to people belonging to other groups. In the two sites in Finnmark, herders preferred to give gifts to members of their herding group regardless of relatedness, although closer kin in the same *siida* were most likely to receive gifts. This pattern matches district-level evidence that kinship structures reindeer herders' cooperation and productivity (Næss et al. 2010; Næss et al. 2012).

Non-kin and distant kin in the QTP sites were more likely to receive gifts if they belonged to the same herding group as the giver. Tibetan herders were slightly more likely to give gifts to close kin belonging to other herding groups (Fig. 2); As in previous cross-cultural studies of cooperation (Henrich et al. 2005; Lamba and Mace 2011; Wu et al. 2015), there was more variance between sites than within, and in this case there was little variation between individuals within sites (Table 2 and Table S5). In the best-fitting model (Fig. 1), 46.4% of the variance was explained by the between-site differences in the interaction between relatedness and herding group membership, while the varying slopes for relatedness explained a further 24.2% (Table 2 and Table S5). In a null model with only varying intercepts for egos nested in sites, 85.5% of the variance was explained by differences between sites (Table S5). Overall, there were no systematic biases in parameter estimates or variances across sites (Fig. 1).

Despite being given anonymously, gifts were reciprocated at higher rates than expected by chance, especially among herders in the two sites in Finnmark, where 26.32 - 28.17% of gifts were reciprocated (Fig. S4). There was strong assortment on gift giving within herding groups, with assortativity coefficients ranging from 0.56 to 0.82 in Finnmark and from 0.26 to 0.61 in QTP. Participants did not preferentially give gifts to same-sex herders in most of the study sites, with the exception of Jilehe and Tawa in QTP; in these two sites, annual average income per household is lower compared to other sites in China. In the two Saami sites, the lack of assortment on sex is likely due to male-bias as a consequence of most licensed herders being male.

Measures of indirect connections were not associated with herd sizes (Table S2), suggesting that direct social bonds (i.e. gifts, in this case) are more important for pastoralist cooperation than how herders are connected to third parties and beyond.

In the four Tibetan sites, modularity was higher than expected by chance, implying a stronger community structure featuring dense clusters of individuals giving gifts to one another (Fig. S4). In Karasjok, modularity was slightly lower than expected by chance, with only 4.9% of the randomly generated modularity scores being less than the observed modularity; modularity scores in Kautokeino were indistinguishable from chance. This suggests more instances of cooperation between clusters of herders in Finnmark compared to QTP, potentially resulting from increased interdependence due to larger per-capita herds operating in a more spatially constrained environment.

Herd sizes are different between the two countries, on average, where *Saami* pastoralists kept larger herds compared to people on the QTP (Fig. S5). We use Gini coefficients, a commonly used measure of wealth inequality, to investigate the inequality in herd sizes (Levine 2015). Gini coefficients are higher within the Tibetan sites (range: 0.385 – 0.454) than within Finnmark (range: 0.257 – 0.292); Tibetan Gini coefficients are slightly lower (i.e. higher equality) than reported by Levine (Levine 2015). Across different herding groups in the Tibetan sites, herders receiving more gifts had below-average herd sizes (Fig. 3 and Fig. S6), indicating that gifts tended to go to poorer herders, contrary to patterns observed among East African pastoralists, who gave gifts to wealthier social partners (Glowacki et al. 2016). This pattern was not associated with age (Fig. S6 and Table S2) and it likely driven by the Tibetan herders' general preference to give gifts to poorer herders, as stated during their interviews. In contrast there is no association between gifts and herd size in either of the Saami sites. Between-subject differences accounted for almost all variance in predicting herd size (99.6%); there was almost no variation between sites (0.4%; Fig. S7).

We also investigated the stated reasons for giving gift to each particular person in the gift game. For Saami reindeer herders, 34% of the gifts were given for reasons of 'current or future reciprocity'; giving to 'good herders' (18%) was also a common reason (Thomas et al. 2015). 'Good herders' in this case means being experienced and respected herders from their local point of view. Very few of Saami herders reported that they will give to the poor (3%) or to family (16%). Among Tibetan herders, the most popular reason for giving gifts was 'Family' (32%); 22% of gift givers also reported that the recipients were poorer than themselves, and they gave gifts as a donation (see Table 3 for the full text of self-report reasons of giving gifts in the two countries). Only 11% of stated reason were for reciprocity. In short, *siida* members were more likely to report that they preferred to give because of the potential for future reciprocity compared to the Tibetan herders (see Table S6, Chi-square=11.51, df=2, P=0.003).

Discussion

Through analyzing the social networks that emerged from allocation decisions in an economic game, we found that although most variation in gift giving occurred between sites, there were comparable patterns within the same country as well as broad similarities regardless of study site. Pastoralists strongly depended on members of their herding groups, especially close relatives. Tibetan herders in China were more likely to give gifts to their close relatives who might not live in the same herding group compared to reindeer herders in Norway. In pastoralist societies, family members can be spread over great distances meaning that it is difficult to provision these kin, especially in harsh environments where the chance of daily interaction is small. Among Tibetan herders, close kin in the same herding group are geographically and psychologically close and may be considered members of the same household who might be supported by other means. A similar result was also found in a hunter-gather group where sharing within the same camp was not very frequent (Marlowe 2004).

Overall, herders rely on a combination of kin (Næss et al. 2010) and the social institution of their herding group, as reflected by their gift-giving decisions. Saami reindeer herders indicated that they preferred to give more because of expected 'current or future reciprocity', whilst Tibetan yak herders reported that they preferred to give gifts to 'family members'. Self-report data are widely used by demographers, psychologists and other social scientists as a direct and simple way to understand people's preferences and/or local norms,

although sometimes people say one thing while doing another (Du and Mace 2018; Thomas et al. 2018b). Due to the nature of conducting gift games over long periods of time, we cannot be completely sure that at least some of the reciprocity observed was not due to participants arranging, outside of the game, to give gifts to one another (Wiessner 2009; Gervais 2017). Even if such behavior occurred, the games would still be collecting information about real-world relationships and thus would be indicative of important instances of reciprocity.

Sociality arises when there are more benefits than costs to living in a group. The relations between different dyads living in the group can be represented as a social network. Social networks evolve when individuals can balance their costs and benefits in order to maximize their fitness. Smith et al (2016) show that the likelihood of reciprocal cooperation is more frequent in stable hunter-gatherer communities than in more unstable bands; in the less stable environment, demand-sharing and tolerated theft occur more often. Here, the social and economic situation is different in two pastoralist societies, where reindeer herders in Norway live in a more stable and economically better environment compared to the Tibetan herders in China who are living in less developed conditions. Keeping stable relationships with kin and non-kin in the same herding group will help secure their livelihood. Our results also show that, among Tibetan herders, cooperation is more kin-based. Giving gifts as a donation was also important for Tibetan pastoralists but not for Saami herders. Showing generosity might be an important strategy in cooperation because it increases social status while, at the same time, increasing the chance of receiving more help if in need (Gurven et al. 2000). We also argue that people tend to show they are generous so that everyone else in the group will know their prosocial tendencies, helping them gain higher social status. In addition, Tibetans are Buddhist, where teachings advocate generous behavior; even, or perhaps especially, in religious communities, costly acts can be acts of status enhancement (Power 2016).

Future research should tie in observational measures of cooperation—especially costly forms of cooperation, such as labor investment—as well as measures of reproductive success to produce a more comprehensive evolutionary account of social behavior in pastoralist societies. Beyond pastoralism, our results have relevance for the role of social institutions, population structure and the multilevel organization of human communities (Dyble et al. 2016)(Dyble et al. 2016) in shaping observed similarities and variation across cultural groups.

Ethics

This research was approved in part by the University College London research ethics committee and by Lanzhou University. Fieldwork in Kautokeino, Norway, was undertaken in accordance with the "General guidelines for research ethics" as stipulated by the Norwegian National Research Ethics Committee (NNREC; https://www.etikkom.no/en/). Specifically, interviews where undertaken in accordance with NNREC's ethical checklist by: (1) obtaining written informed consent; (2) ensuring that no dependent relationship exists that could influence the subjects' decision to give consent; and (3) guaranteeing anonymity and confidentiality of the informants. See SI Text for descriptions of the study sites and data collection procedures.

Data, code and materials

Data are deposited in [URL; DOI] and code to reproduce our analyses is available from https://github.com/matthewgthomas/hierarchies-gifts/

Competing interests

We have no competing interests

Author contributions:

MGT, DJ, BJB, RM and MWN designed research; MGT and DJ collected data; MGT analyzed data; and MGT, DJ, BJB, RM and MWN wrote the paper.

Acknowledgements

We thank the reindeer and yak herders for their help and their patience. Thanks also to our field assistants in Norway (Ida Ophaug and Jon Mikkel Eira) and in China (Bai Pengpeng, Jiu Cili, Gong Bao Cao).

Funding

Fieldwork and data collection in both sites was funded by "HIERARCHIES", funded by the Norwegian Research Council (project number: 240280). M.W.N. and B.J.B. were financed by "HIERARCHIES", funded by the Norwegian Research Council (project number: 240280). M.W.N., B.J.B. and M.G.T. were financed by "ReiGN: Reindeer Husbandry in a Globalizing North – Resilience, Adaptations and Pathways for Actions", which is a Nordforsk-funded "Nordic Centre of Excellence" (project number 76915). D.J. was funded by the China Scholarship Council. M.G.T. and R.M. received funding from European Research Council Advanced Grant AdG 249347 to RM. R.M. and D. J were also funded by Lanzhou University.

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Figure and table captions

Fig. 1: Network diagrams showing gifts given between participants in each field site: A-D are Cairima, Duolong, Jilehe and Tawa in Tibet; E and F are Karasjok and Kautokeino in Finnmark. Nodes represent individuals within each community, coloured by herding group membership; larger nodes received more gifts. Edges show gift giving, where thicker arrows indicate larger gifts. Spatial location in the figures is arbitrary and does not represent spatial location in the site.

Fig. 2: Log-odds from the best-fitting multilevel logistic model predicting gift giving; this model contains varying intercepts and varying slopes (Table S3). Points show medians, colored by study site; thick lines are 80% credible intervals; and thin lines are 95% credible intervals. Top panel shows varying intercepts for each site (intercepts for individuals within sites not shown); remaining panels show slopes for each predictor, varying by site. Grey dotted line represents no effect; each parameter estimate was statistically distinguishable from log-odds = 0. Parameter estimates and variances are shown in Table S3; Fig. 2 shows predictions from this model.

Fig. 3: Predicted herd size (standardized) from number of gifts received (in-degree in the gift network) for males (green) and females (blue) in Tibetan pastoralists. The model was fitted on the subset of 1,071 herders for whom we had information about age, sex, and herd size. See Methods for model specification and Table S2 for the candidate set of models. Lines show parameter estimate medians and shaded ribbons are 95% credible intervals. See Table 1 for standard deviations in herd size to ease interpretation of these z-scores.

Table 1: Descriptive statistics of the samples in each site. 'Mean *r* in groups' refers to the grand mean coefficient of relatedness within each herding group within study sites.

Table 2: Estimated variances and variance partition coefficients (VPCs) for varying intercepts and slopes in the best-fitting multilevel model (Table S5). Parentheses show standard deviations of the variance estimates; note that this was not calculated for the population average intercept, as this was a logistic regression without an error term.

Table 3: Self-reported reasons of giving gifts in *Siida* and *ru skor*. The reasons of giving gifts were listed in descending order.

Tables

Table 1: Descriptive statistics of the samples in each site. 'Mean *r* in groups' refers to the grand mean coefficient of relatedness within each herding group within study sites. Note that in the Finnmark: Kautokeino site, there was one herder whose gender we did not know.

Study site	N	No. givers	No. gifts	Mean (SD) age	No. females	No. males	No. groups	Mean (SD) N in groups	Mean *r* in groups	Mean (SD) herd size
Finnmark: Karasjok	75	30	71	51.94 (12.14)	14	61	9	8.33 (4.72)	0.19	438.67 (185.38)
Finnmark: Kautokeino	137	30	76	47.76 (11.35)	40	96	24	5.71 (3.33)	0.07	431.03 (195.27)
Tibet: Cairima	239	138	212	37.4 (18.56)	111	128	60	3.98 (4.26)	0.17	49.24 (42.92)
Tibet: Doulong	256	147	212	34.73 (17.09)	129	127	50	5.12 (5.57)	0.17	52.79 (39.38)
Tibet: Jilehe	349	213	342	36.82 (18.79)	171	178	28	12.46 (18.05)	0.09	75.26 (54.66)
Tibet: Tawa	348	197	301	37.65 (17.06)	191	157	34	10.24 (11.69)	0.15	60.24 (45.66)
Totals	**1,404**	**755**	**1,214**	**99 (99)**	**656**	**747**	**205**	—	—	—

Table 2: Estimated variances and variance partition coefficients (VPCs) for varying intercepts and slopes in the best-fitting multilevel model (Table S5). Parentheses show standard deviations of the variance estimates; note that this was not calculated for the population average intercept, as this was a logistic regression without an error term.

Variance component	Variance	VPC
Population-average intercept	0.133	1.80 %
Egos nested in sites intercepts	0.002 (0.05)	0.03 %
Study site intercepts	0.679 (0.82)	9.22 %
Relatedness slopes	1.78 (1.33)	24.16 %
Herding group membership slopes	1.358 (1.17)	18.44 %
Relatedness × herding group slopes	3.414 (1.85)	46.36 %

559
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561 Table 3: Self-reported reasons of giving gifts in *Siida* and *ru skor*. The reasons of giving gifts were listed in
562 descending order of prevalence.

Siida **(Norway)**		***ru skor*****(China)**	
Reasons	**Number**	**Reasons**	**Number**
Current or future reciprocity	24 (34%)	Family	307 (32%)
Good herders	13 (18%)	Need help/Poor	207（22%）
Family	11 (16%)	Current or future reciprocity	196（21%）
Young/new owners	7 (10%)	Friends	151（16%）
No reason given	6 (8%)	No reason given	85（9%）
Deserving	3 (4%)	**Total**	**946 (100%)**
Lazy	3 (4%)		
Need help/Poor	2 (3%)		
Friends	1 (1%)		
Selfish	1 (1%)		
Total	**71(100%)**		

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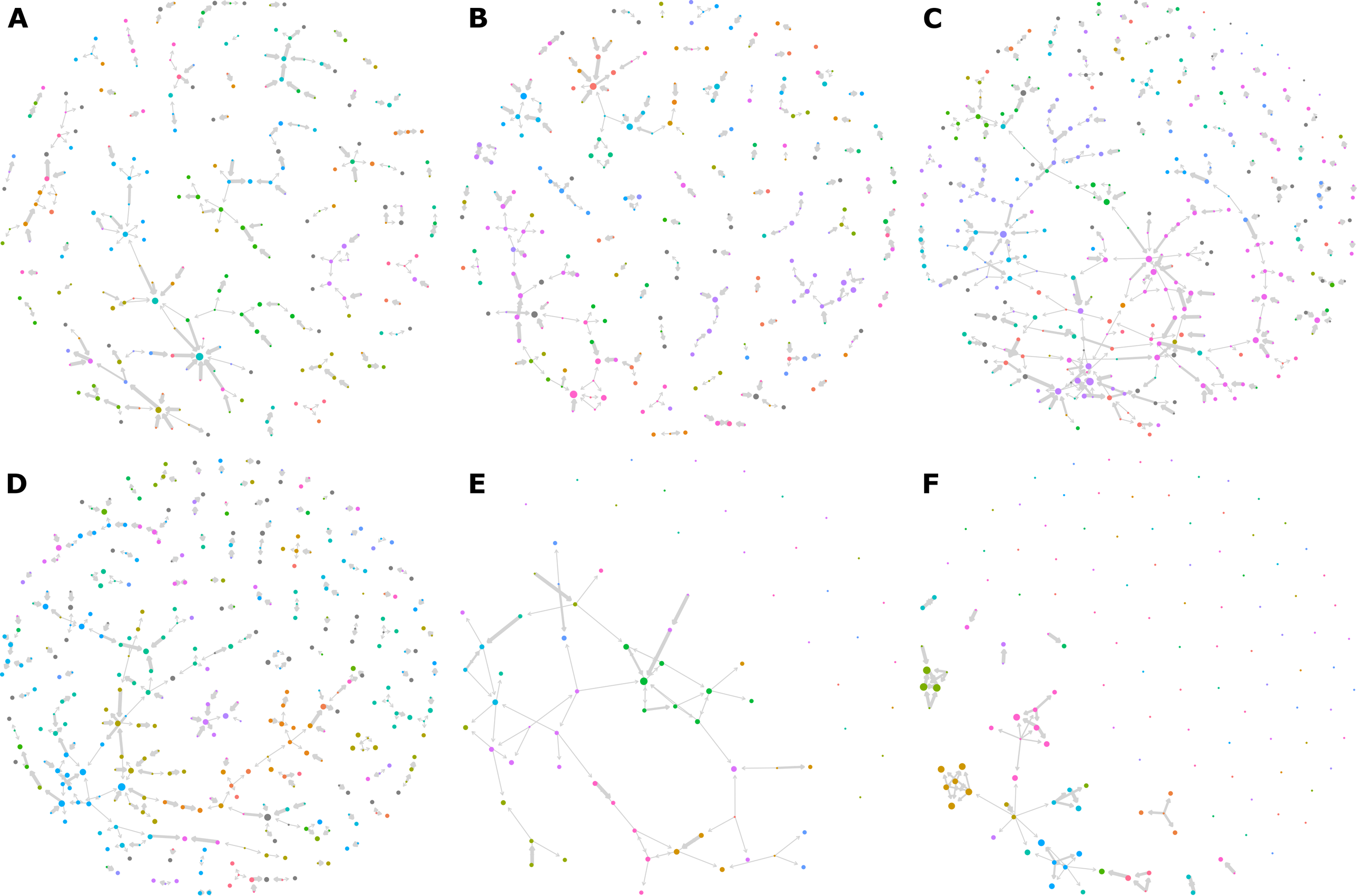
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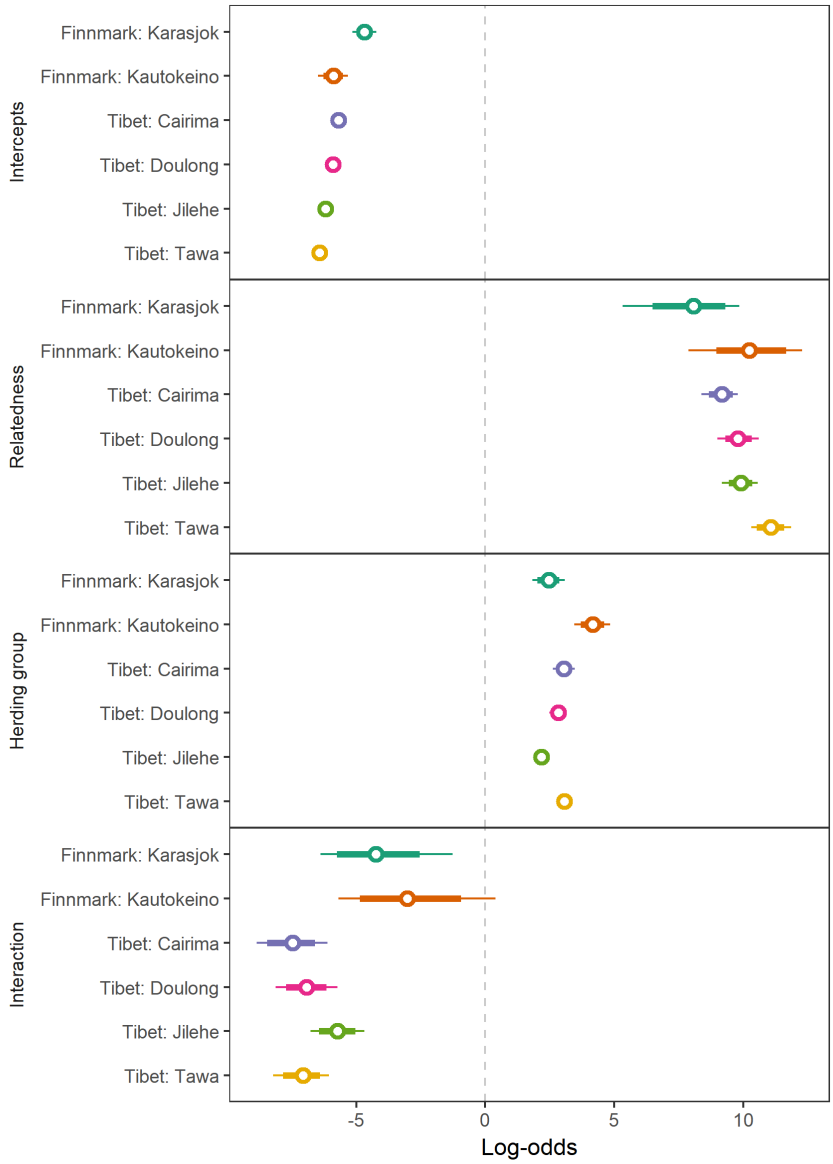
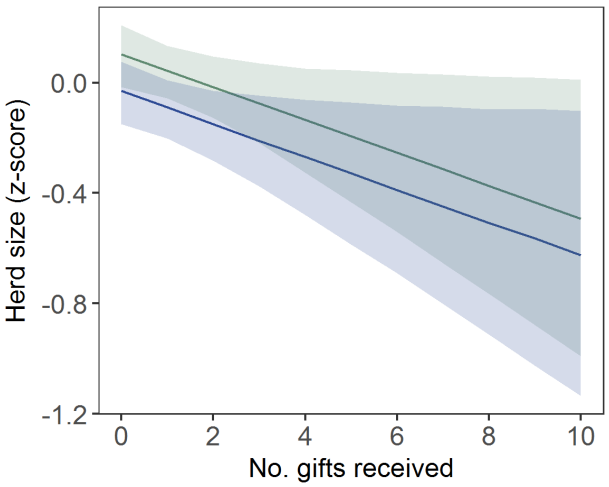

Intercepts
Relatedness
Herding group
Interaction
Finnmark: Karasjok
Finnmark: Kautokeino
Tibet: Cairima
Tibet: Doulong
Tibet: Jilehe
Tibet: Tawa
-5
0
5
10
Log-odds


Herd size (z-score)
0.0
-0.4
-0.8
-1.2
0
2
4
6
8
10
No. gifts received