Evolution and Human Behavior 47 (2026) 106814

Contents lists available at ScienceDirect

Evolution and Human Behavior

journal homepage: www.elsevier.com/locate/ens

Gender differences in social networks under subsistence changes

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ARTICLE INFO

Keywords:
Gender difference
Market participation
Post-marital residence patterns
Social networks

ABSTRACT

Sexual selection theory suggests that gendered social strategies are universal outcomes of reproductive competition, yet recent cross-cultural studies show that these strategies are shaped by socio-ecological factors although they remain insufficiently examined. In particular, little is known about how gendered strategies adapt during periods of rapid social and economic changes. To this end, we examine gender differences in scale and composition of ego-networks, guided by two main hypotheses: that gender roles are shaped by (i) market participation, and (ii) post-marital residence pattern. Using data from 1169 married women and men across 14 Tibetan villages undergoing economic and kinship-system transitions, we applied Bayesian multilevel models to analyse core social relationships. Our findings show that, as men increase their participation in market economies, their networks become more kin-centred – strengthening biological kin ties while loosening friend ties – reflecting an instrumental restructuring of social relationships in response to changing economic roles. In contrast, women's networks remain largely unaffected, likely reflecting the persistence of caregiving responsibilities and strong local embeddedness. Post-marital residence patterns impose comparable trade-offs for both sexes: philopatric individuals prioritise biological kin, while affinal kin can effectively substitute for natal relatives when biological kin become less accessible, forming a balanced, bilateral cooperative network that integrates both kin types. This study underscores that women sustain stable and cohesive social ties across socio-economic transitions, while men adapt their networks more flexibly in response to shifting economic roles.

1. Introduction

Humans exhibit a remarkable capacity to form diverse social relationships fulfilling distinct evolutionary roles (Apicella, Marlowe, Fowler, & Christakis, 2012). Kin-based cooperation centres on resource sharing and childcare (Hrdy, 2007), while non-kin alliances more highlight access to novel information and economic opportunities beyond the family (Putnam, 2000). How gender structures these relationships has long been central in anthropology, psychology and social sciences (Falk & Hermle, 2018; Mattison et al., 2021, 2022; McDonald & Welling, 2023; Trivers, 1972; Williams, Krems, Ayers, & Rankin, 2022). Gendered social strategies are flexible and shaped by social, ecological and cultural contexts (Ge, Dongzhi, & Mace, 2024; Henrich et al., 2011; Mattison et al., 2021; Micheletti, Ruxton, & Gardner, 2020; Power & Ready, 2019). Yet, how gendered strategies adapt during rapid social and economic transitions remains poorly understood. To address this gap, we examine gendered social strategies in a Tibetan population undergoing a transition from traditional subsistence practices to wage-labour economies, alongside a shift in inheritance from female-biased to gender-neutral (Huang, Bai, Zhou, Mace, & Du, 2025). By considering market participation and post-marital residence patterns, this case study provides valuable insight into the adaptive nature of gendered social strategies.

Evolutionary frameworks provide insights into gendered social behaviours. Parental investment theory (Trivers, 1972) posits that gender-specific trade-offs in reproduction generate distinct social orientations: women maintain smaller, kin-centred networks, whereas men cultivate broader, status-oriented ones (Dávid-Barrett et al., 2015; Dunbar & Spoors, 1995; Fox, Scelza, Silk, & Kramer, 2022; Silk, 2007; Vigil, 2007). Human life-history traits, including cooperative breeding (Kramer,

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https://doi.org/10.1016/j.evolhumbehav.2025.106814
Received 3 June 2025; Received in revised form 30 October 2025; Accepted 9 December 2025
Available online 13 December 2025

2010) and post-reproductive kin support (Hawkes, O'Connell, Jones, Alvarez, & Charnov, 2017), further underscore women's central role in kin cooperation across generations. Girls' early domestic roles (Kramer, 2005) and boys' freer peer networks (Schlegel & Barry, 1991) establish gendered trajectories, while older women continue investing heavily in kin (Dávid-Barrett et al., 2016). However, biological models alone cannot explain human gender differences. The prevalence of monogamy constrains men's opportunities to gain reproductive success through multiple partners, reducing male-male competition (Emlen & Oring, 1977). Paternal investment and biparental care align male and female reproductive interests (Geary, 2000), while men's fitness may decline with additional partners (Schacht & Mulder, 2015). Therefore, human gendered social strategies cannot be fully explained by biological models which often implicitly assume that men have the opportunity to pursue multiple mates (Ross et al., 2023).

The sexual division of labour further structures gendered strategies, as men and women specialise in complementary roles that enhance household productivity (Becker, 1991). Across societies, men engage in physically demanding or mobile tasks (e.g., hunting, farming, herding), while women focus on childcare and domestic labour (Murdock, 1937; Wood & Eagly, 2002). However, this division is flexible, adapting to ecological and cultural contexts (Anderson, Chilczuk, Nelson, Ruther, & Wall-Scheffler, 2023; Chen, Ge, Zhou, Du, & Mace, 2023; Du & Mace, 2018; Goodman, Griffin, Estioko-Griffin, & Grove, 1985; Hoffman, Farquharson, & Venkataraman, 2023; Wood & Eagly, 2002). Women hunt or trade when compatible with childcare or supported by norms (Anderson et al., 2023; Hoffman et al., 2023; Starkweather, Shenk, & McElreath, 2020). Context-dependent gendered labour give rise to flexible gendered social strategies, enabling individuals to adapt to the varying demands of their roles (House, Silk, & McAuliffe, 2022; Kraft et al., 2022). Integration into market economies introduces new dynamics. On one hand, it can reinforce traditional divisions through gendered task rewards (Harpending & Pennington, 1990) or barriers (He & Wu, 2017). On the other hand, market economies can facilitate women's roles as providers through increasing demands for female labour (e.g., in the service sector) (Olivetti & Petrongolo, 2016), reducing resistance to women's wage employment (Fernández, Fogli, & Olivetti, 2004) and expanding institutional childcare supports (Duflo, 2012). Thus, market economies can either reinforce traditional patterns of female caregiving and male provisioning or erode them, giving rise to new configurations of gendered social strategies. However, most research often focuses on women alone (Colleran, 2020), ignore explicit gender differences (Henrich et al., 2011), or provides household level analyses that obscure individual trade-offs (Hackman & Kramer, 2021). Furthermore, little attention has been paid to how both men's and women's social strategies adapt during periods of rapid changes, particularly subsistence transitions. Building on these frameworks, our study investigates how both men's and women's social strategies adapt to market participation in a Tibetan population transitioning from traditional subsistence practices to wage-labour economies (Huang et al., 2025).

Household task allocation reflects inter-sexual bargaining over resources control, kin support and relatedness among household members (Agarwal, 1997,). The gender with greater bargaining power often secures more favourable divisions of labour (Chen et al., 2023), enabling engagement in personal pursuits and broader social networks, sometimes conflicting with household interests (Agarwal, 1997; Manser & Brown, 1980). Men's control over key resources like livestock, land or cash positions them in external provisioning roles, while women focus on domestic work and childcare (Holden & Mace, 2003; Shenk, Begley, Nolin, & Swiatek, 2019). Access to kin further shapes these dynamics: women with nearby kin can mobilise childcare support for outside work (Seabright et al., 2022). Relatedness within households also affects bargaining outcomes: higher relatedness may increase labour obligations due to shared resource demands or facilitate alliances that redistribute workloads onto non-natal kin (Chen et al., 2023; Wu et al., 2013). Post-marital residence pattern – determining kin access, resource control and decision-making authority – acts as a structural indicator of intersexual bargaining power and shape household organisation, gender roles and social strategies. Gender-biased dispersal influences proximity to biological and affinal kin, shaping trade-offs between these cooperative ties (Power & Ready, 2019). Biological kin are prioritised over affinal kin (Hamilton, 1964a, 1964b; Nowak, 2006), however, dispersing gender faces higher costs to maintain contact with natal kin, making nearby affinal kin an adaptive substitute (Seabright et al., 2022). Intergroup and long-distance ties can buffer risks and diversify resource access (Pisor & Ross, 2022), while kin cooperation can also create conflicts over shared resources (Dong, Gavrilets, Qin, & Zhang, 2024; Hadley, 2004; Kasper & Mulder, 2015). Building on these insights, our second focus is to examine how gender differences in social strategies are shaped by post-marital residence in a population with diverse residence patterns, which generate distinct gendered cooperation dynamics (Huang et al., 2025).

2. Hypotheses

To examine how gender differences in social strategies are influenced by market participation and post-marital residence pattern, we use empirical data on core social relationships among 1169 married women and men across 14 Tibetan villages. We assess both the scale and composition of ego-networks – including biological kin, affinal kin and friend density – to comprehensively understand how these relationships adapt in a Tibetan population transitioning from traditional subsistence to market economy. Participation in market activities alters trade-offs between kin and non-kin cooperation, while residence patterns mediate the balance of investment between biological and affinal kin.

Hypothesis 1 (Market participation): Traditional production systems generate gendered social patterns: women maintain higher biological kin density, while men maintain higher friend density. As economies become market-oriented, the sexual division of labour and gender-specific presence in local social life change. Men increasingly engage in external wage labour, while women often engage in part-time agricultural wage labour alongside other villagers (Zhou, 2010). Therefore, we hypothesise that (*a*) men's market participation should increase biological kin density, but (*b*) decrease friend density, reflecting stronger kin reliance and fewer friendship ties due to absences. Women's market participation should (*c*) maintain comparable biological kin density while (*d*) increase friendship density, as localised work preserves community connections while male absence increases female engagements in status-oriented relationships. Taken fundamental patterns of gendered social strategies based on traditional production systems together, we predict that (*e*) men will narrow the gap in biological kin density relative to women, while (*f*) women will narrow the gap in friend density relative to men. We further anticipate that these trade-offs between kin and friendship ties will balance each other out, so that market participation will not have gender-specific effects on (*g*) affinal kin or (*h*) overall density. Therefore, we expect no significant changes in gender differences in (*i*) affinal kin or (*j*) overall density.

Hypothesis 2 (Post-marital residence pattern): Co-residence tends to accelerate rates of reproduction (Du et al., 2023), while fertility-limitation policies reduce generational overlap and thus lower competition. Accordingly, philopatry with greater kin proximity is expected to promotes kin cooperation rather than competition. Most marriages occur within this study area, allowing both biological and affinal kin to remain accessible (e.g., patrilocal women can maintain ties with biological kin in nearby villages). Tibetan kinship is bilateral (Gengdengcuo., 2015), reducing distinctions between biological and affinal kin, so affinal kin may substitute for biological kin when distance increases. Under matrilocal residence, (*a*) women should have especially higher biological kin density (i.e., women's advantages under matrilocality plus initial biological sex-based advantages) but (*b*) lower affinal kin density compared to men. Under patrilocality, we hypothesise (*c*) no

obvious gender difference in biological kin density, as women's disadvantages under patrilocality are offset by their biological sex-based advantages. However, (*d*) women should have higher affinal kin density. Under bilocal residence where both wife's and husband's kins are nearby, we hypothesise that (*e*) women have higher biological kin density (i.e., only their initial biological sex-based advantages) compared to men, however, (*f*) there should be not gender difference in affinal kin density. For friend density, we hypothesise that (*g*) residence patterns will not cause gender differences. Integrating dynamics of biological kin, affinal kin and friendship density, we hypothesise that (*h*) women consistently show higher overall network density than men across residence patterns.

An overview of our predictions on how the overall scale and three compositional components of married women's and men's ego-networks – and their associated gender differences –shaped by market participation and post-marital residence pattern, can be seen in Table 1.

3. Materials and methods

3.1. Causal framework

Figure 1 illustrates a directed acyclic graph (DAG) showing the main factors hypothesised to influence egocentric network (includes all four types of network density; details in the Data preparation-Outcome section). DAGs are tools for visualising causal relationships, helping identify confounders and guide model design for unbiased causal inference (Pearl, Glymour, & Jewell, 2016). According to our DAG, gender, rooted in biological sex difference and sexual division of labour, influences structures of ego-networks (Gender → Density). Gender differences in market participation are expected based on sexual division of labour (Gender → Market). Age is expected to influence ego-networks, as shifting interests and priorities are tied to different life stages (Age → Density). Age serves here as a proxy for unobserved dynamics within inheritance systems and subsistence practices, both of which influence post-marital residence patterns (Age → Residence). Age also serves as a proxy for unobserved family labour division affecting market participation, with older individuals engaging more in herding and farming, while younger individuals traveling more for wage labour and family purchases (Age → Market). Post-marital residence patterns shape the structures of ego-networks by determining the presence of biological relatives, affinal relatives, and unrelated acquaintances, as well as influencing household bargaining power (Residence → Density). Additionally, post-marital residence patterns shape household bargaining power, thereby influencing the extent of livelihood transitions, here in terms of participation in market economies (Residence → Market). Wage-labour economy promotes friend ties over kin-based support, leading individuals to be more integrated into markets to prioritise friendships and have fewer ties with biological and affinal relatives (Market → Density). Unobserved variables at individual- and village-level, like personality traits, past experience, and distance to markets, influence core social networks ($U_{Individual}$ → Density and $U_{Village}$ → Density). Additional details about the hypothesised causal relationships between each pair of factors, as well as between factors and ego-networks, are provided in the supplementary materials (see Directed acyclic graphs section).

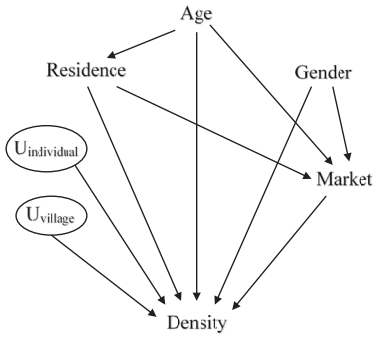

Fig. 1. Causal graph summarising our beliefs about the data-generating process. Density refers to any form of network density (overall, biological kin, affinal kin, or friendship). Market represents the frequency of participation in market activities. Residence denotes the post-marital residence pattern at the village level. Circles denote unobserved variables at village- and individual-level.

Following our causal assumptions, we first estimated the gender-specific effects of market participation, controlling for age and post-marital residence patterns, as implied by our DAG. Next, we estimated the gender-specific effects of post-marital residence patterns, additionally conditioning on age, as implied by the DAG. We included individual and village IDs in all models, which served as proxies for unobserved variables to account for unmeasured confounders at both individual and village levels.

Table 1
An overview of predictions about the overall scale and three compositional types of married women's and men's ego-networks under different scenarios.

Scenario		Biological kin	Affinal kin	Friend	Overall
H1: participation in market activity					
More market participation	Women	—	—	↑	—
	Men	↑	—	↓	—
	Gender difference	Female-biased (↓)	Female-biased (−-)	Male-biased (↓)	Female-biased (−-)
H2: post-marital residence pattern					
Matrilocal	Gender difference	f > > m	f < m	f = m	f > m
Patrilocal	Gender difference	f = m	f > m	f = m	f > m
Bilocal	Gender difference	f > m	f = m	f = m	f > m

'↑' represents a positive trend, '↓' represents a negative trend, and '—' represents no significant trend.
'f = m' represents there is not gender-specific difference.
'f < m' represents that men have higher certain type of network density than women.
'f > m' represents that women have higher certain type of network density than men.
'f > > m' represents that women have especially higher certain type of network density than men.

3.2. Study area

Data were gathered in a town in the north-western area of Diqing Tibetan Autonomous Prefecture, Yunnan Province, China. This administrative town includes three townships (He et al., 2015). Over 90 % of the local population consists of Tibetans, who share a common ethnic heritage and language (Wang, 2018). Ethnographic observations showed that subsistence in the study region was a combination of farming and herding (Zhou, 2010). Women play a central role in farming activities, whereas men contribute more heavily to herding (Zhou, 2010). In recent years, many households have leased their land to agricultural companies, with local residents subsequently employed as wage labourers by these companies. Livestock raising is increasingly pursued for household self-sufficiency, though only a minority of families engage in large-scale herding for income generation. With ongoing economic development, men have entered the market sector predominantly through construction (e.g., building and renovating Tibetan houses) and transportation (e.g., hauling sand for quarry operations). More recently, women have increasingly engaged in part-time wage labour, particularly through employment with agricultural enterprises

operating on locally leased land. This type of temporary agricultural labour opportunity is rotated according to household number and labour availability. A clear shift in subsistence pattern have been evident, from a traditional mode based on agriculture and pastoralism, toward a market-oriented economy (Huang et al., 2025). At the same time, inheritance practices have transitioned from a historically female-biased system to a more gender-neutral structure (Huang et al., 2025). Tibetans practice zuò jiā (坐家), in which parents designate one offspring to co-reside with them after marriage and inherit the majority of the parental estate (Huang et al., 2025). In older generations, daughters were more chosen as an inheritor, however, in more recent generations, sons and daughters are treated equally in inheritance matters (Huang et al., 2025). Marriage mostly takes place within the same township, following one of three post-marital residence patterns: matrilocal, patrilocal or bilocal. In the bilocal arrangement, couples have both of their parents in the same village (Du et al., 2023).

3.3. Data collection and management

Demographic data collection took place in one township, including 17 villages. For further information on the similarities and differences among these villages, refer to previous papers (Du et al., 2023; Huang et al., 2025). Demographic information was gathered in 2015, 2021 and 2023, with support from local interpreters. We carried out thorough interviews with all adults in each household, employing paper questionnaires to gather demographic information at both individual and household levels. Comprehensive individual details were documented, including name, age, zodiac sign (to improve birth year accuracy), gender, birthplace, and information about sibship (both living and deceased). Parental details were also recorded, covering name, age, zodiac sign, current residence, and, if deceased, the year and location of death. In 2015, our study focused on 13 villages, excluding four mountain villages. By 2021, we included these 4 villages and updated the demographic data previously collected. In 2023, demographic data of all 17 villages were updated again. In addition, unique personal identities (personal IDs) and household identities (household IDs) were coded, and siblings were linked using mother's and father's IDs. In 2023, there were 3583 local residents living in our study area (1815 females and 1768 males).

Egocentric network data were collected in 2023, including 14 villages (see table S1). Married respondents were asked to nominate up to 5 individuals from different households with whom they are regularly in contact within these 14 villages. By limiting nominations to the five most significant relationships, the design reduced respondent bias during data collection and ensured comparability across participants. Particularly, we restricted participants' nomination within our study area, enabling us to focus on gender differences in social strategies shaped by normative expectations of gender roles related to sexual division of labour and bargaining power in a certain context, as well as to avoid bias in our analyses that could arise from excluding ties outside the study area due to missing information. Detailed information of each nominee was recorded to identify personal ID, allowing linkage to information collected previously. Self-reported relationship to nominator was documented and divided into four types: biological kin, affinal kin, (non-relative) friend, and both biological and affinal kin. Frequency of visits to the town centre (or markets) or more distant areas were recorded for each respondent. There were 1212 married respondents. A total of 1169 respondents (691 females and 478 males) reported at least one nomination. The average number of nominations was 4.01 ± 1.34 (see table S2). The average number of nominations for biological kin was 1.67 ± 1.40, the average number of nominations for affinal kin was 0.94 ± 1.04, and the average number of nominations for friends was 1.41 ± 1.41 (see table S2). It was preponderant to note that 19 among the 4684 ties (0.40 %) between nominators and nominees, as well as 333 of the 3250 ties (10.25 %) among nominees, were reported as both biological and marital. Therefore, the total number of nominations did not precisely correspond to the sum of nominations for biological kin, affinal kin, and friends. Since our study focused on gender differences within each category, this overlap does not affect the analyses. More details about data collection and management were in electronic supplementary materials.

3.4. Data preparation

Outcome Following Colleran, kin density (i.e., the extent of interconnectedness among kin within an ego-network) offers a more precise view of kin ties within ego-networks than simply the size or proportion of kin (Colleran, 2020). Similarly, network density captures the overall connectivity within ego-networks, providing more information than the size of ego-networks. Two ego-networks of equal size and/or proportion, could differ greatly in their capacity to mobilise resources or transmit information among network members if one is highly interconnected while the other is sparse (Marsden, 2002; Muller & Peres, 2018). Network density thus provides a more accurate measure of resource and information flow, while avoiding the biases inherent in relying solely on size or proportion (Marsden, 2002; Muller & Peres, 2018). Understanding the dynamics among nominees is also crucial and thus we separated kin density into biological and affinal, which captured more nuances (Fig. 2). In total, four types of network density were created and analysed – overall network density, biological kin density, affinal kin density, and friend density. Network density was computed as the number of reported ties divided by all candidate ties (see Eq.1 in supplementary materials 'Details about models' section).

Predictors The reported gender was used as a categorical variable. Market participation was measured by the frequency of visits to town centres, markets, or distant locations. This variable was derived by adding 1 to the frequency, applying a natural logarithmic transformation, and subsequently standardising the values. Standardisation was done by subtracting the mean and dividing by the standard deviation for each value. Post-marital residence was categorised based on whether the husband and/or wife move away from their natal village after marriage. It was divided into three groups: matrilocal (living in the wife's natal village), patrilocal (living in the husband's natal village), and bilocal (living village is natal village of both wife and husband). The reported age was mean-centred and divided by one standard deviation.

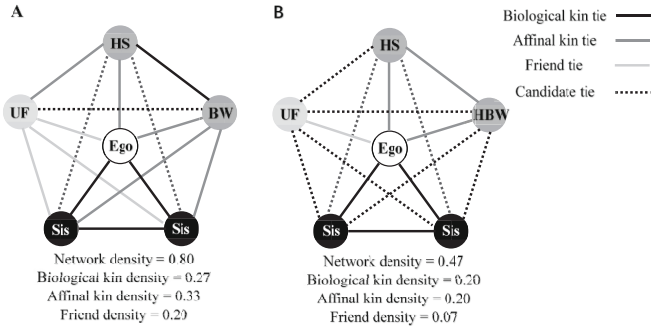

Fig. 2. The overall-network density, biological kin density, affinal kin density, and friend density differ between two ego-networks that have the same composition of alters (nominations for two biological kin, two affinal kin and a unrelated friend). Alters are defined from the perspective of the ego: Sis = sister, HS = husband's sister, BW = brother's wife, UF = unrelated friend and HBW = husband's brother's wife. Each type of density equals to this type of real ties divided by all candidate ties. In A, the ego-network includes five alters and is highly interconnected, with 12 of the 15 candidate ties established, including 4 biological ties, 5 affinal (marital) ties, and 3 friend ties. For example, 'HS' and 'BW' are siblings, and 'HS' and 'UF' are affinal kin because 'UF' is the husband's sibling's wife of 'HS'. Hence, 'UF' and ego are unrelated. In B, the composition of alters is the same as in A, but with fewer ties – with 7 out of 15 candidate ties, including 3 biological ties, 3 affinal ties, and 1 friend tie. Here, 'HBW' is the sibling's wife of 'HS', making them affinal kin.

There were 1169 unique individual IDs and 14 distinct village IDs.

3.5. Data analysis

To analyse our network density measures, we developed a series of Bayesian multilevel models. For any network type, the probability of an individual i successfully forming a tie (p_i) was given as the number of observed ties (T_i) divided by the number of potential ties (N_i), following a binomial distribution (Eq. 1). This probability was contingent on the sum of predictor values, modelled on a logit scale (Eq. 2–3). Eq. 2 estimated the gender-specific effect of market participation, while eq. 3 estimated the gender-specific effect of post-marital residence pattern. In both equations, $G_i = 1$ for females and $G_i = 2$ for males. The term $\beta A_{G[i]}$ represented age effects stratified by gender $G[i]$. The term βR represented effects of post-marital residence PMR_i, which was also stratified by gender (i.e., interaction of gender and residence). The term $\beta M_{G[i]}$ represented gender-stratified effects of market participation M_i. Each model included village-level and individual-level random effects V_{VID} and I_{ID}, respectively, to account for unobserved confounders, modelled as a sum of mean $\overline{V}$ and a z-score ZV_i multiplied by σV for village effects (Eq. 4), and a z-score ZI_i multiplied by σI for individual effects (Eq. 5).

$$T_i \sim Binomial(N_i, p_i) \tag{1}$$

$$logit(p_i) = \beta \mathrm{A}_{G[i]} \times \mathrm{Age}_i + \beta \mathrm{R}[G_i, PMR_i] + \beta \mathrm{M}_{G[i]} \times \mathrm{M}_i + V_{VID[i]} + I_{ID[i]} \tag{2}$$

$$logit(p_i) = \beta \mathrm{A}_{G[i]} \times \mathrm{Age}_i + \beta \mathrm{R}[G_i, PMR_i] + V_{VID[i]} + I_{ID[i]} \tag{3}$$

$$V_i = \overline{V} + ZV_i \times \sigma V \tag{4}$$

$$I_i = ZI_i \times \sigma I \tag{5}$$

We used weakly regularizing priors to impose conservatism on the estimated parameters as well as to prevent the models from overfitting the data. Following priors were used:

$\beta A_g \sim Normal(0, 0.5)$ *for* $g = 1$ *or* 2

$\beta R_{gj} \sim Normal(0, 0.5)$ *for* $g = 1$ *or* $2, j = 1, 2$ *or* 3

$\beta M_g \sim Normal(0, 0.5)$ *for* $g = 1$ *or* 2

$\overline{V} \sim Normal(0, 0.5)$

$ZV_h \sim Normal(0, 1)$ *for* $h = 1, 2, \cdots$ *or* 14

$\sigma V \sim Exponential(1)$

$ZI_k \sim Normal(0, 4)$ *for* $k = 1, 2, \cdots$ *or* 1169

$\sigma I \sim Exponential(1)$

All analyses were carried out in RStudio (v. 4.4.1) (R Core Team, 2024). Posterior distributions for model parameters were generated by running six Hamiltonian Monte Carlo chains, each with 1500 iterations and 500 iterations of warm-up, implemented in the programming language Stan (Team, 2024). Posteriors were processed with the *rethinking* package (McElreath, 2024). We evaluated convergence by examining the effective sample size and Gelman-Rubin diagnostic. All parameters of each model exhibited $\widehat{R}$ values below 1.01 and an effective sample size >1000. Graphs were generated using the packages *dagitty* (Textor, van der Zande, & Ankan, 2023), *dplyr* (Wickham, François, Henry, Müller, & Vaughan, 2023) and *ggplot2* (Wickham, 2023). Outputs were obtained with the assistance of the packages *tibble* (Müller & Wickham, 2023), *officer* (Gohel, Moog, & Heckmann, 2024), *gt* (Iannone et al., 2024) and *gto* (Hughes, 2024).

Predictions were based on models in Eqs. 2–3. Differences between the genders in βR and βM parameters were computed by subtracting the two posteriors and taking the mean. The 90 % credible intervals (CI) were examined to determine whether they exclude zero, indicating statistically meaningful effects.

4. Results

4.1. Gender-specific effects of market participation (H1)

4.1.1. Biological kin density

Our findings revealed that the effects of market participation on biological kin density differed by gender. As market participation increased, men structured their ego-networks with higher biological kin density ($\beta M_{man} = 0.18$, 90 % credible intervals = [0.05, 0.31]; Fig. 3, Fig. S1 and Table S3), in line with our expectation in *H1a*. In contrast, women maintained relatively stable levels of biological kin density across different levels of market participation ($\beta M_{woman} = -0.05$, 90 % CI = [−0.17, 0.06]; Fig. 3, Fig. S1 and Table S3), supporting *H1c*. Gender differences in biological kin density shifted with market participation ($\beta M_{woman-man} = -0.23$, 90 % CI = [−0.40, −0.07]; Fig. 3, Fig. S2 and Table S4), indicating that women's initial advantage in biological kin density diminished as men increasingly concentrated their ego-networks around biological kin, in line with *H1e*.

4.1.2. Affinal kin density

For affinal kin density, the effects of market participation on affinal kin density appeared minimal for both women and men ($\beta M_{woman} = -0.01$, 90 % CI = [−0.11, 0.08]; $\beta M_{man} = -0.03$, 90 % CI = [−0.13, 0.07]; Fig. 3, Fig. S1 and Table S3), consistent with *H1g*. Meanwhile, gender differences in affinal kin density remained negligible across varying degrees of market participation ($\beta M_{woman-man} = 0.02$, 90 % CI = [−0.12, 0.15]; Fig. 3, Fig. S2 and Table S4), consistent with our expectation in *H1i*.

4.1.3. Friend density

For friend density, market participation also had gender-specific effects but in the opposite direction to those observed in biological kin density. As market participation increased, men showed looser friend density ($\beta M_{man} = -0.26$, 90 % CI = [−0.38, −0.15]; Fig. 3, Fig. S1 and Table S3), consistent with *H1b*. In contrast, women still maintained relatively stable levels of friend density across different levels of market participation ($\beta M_{woman} = 0.04$, 90 % CI = [−0.06, 0.15]; Fig. 3, Fig. S1 and Table S3), contrary to *H1d*. Gender differences in friendships covaried with market participation ($\beta M_{woman-man} = 0.31$, 90 % CI = [0.16, 0.45]; Fig. 3, Fig. S2 and Table S4), showing a reduction in the male-biased gap, consistent with our expectation in *H1f*.

4.1.4. Overall density

Market participation did not have obvious influences on overall network density for either women or men ($\beta M_{woman} = -0.02$, 90 % CI = [−0.08, 0.04]; $\beta M_{man} = -0.03$, 90 % CI = [−0.10, 0.04]; Fig. 3, Fig. S1 and Table S3), supporting *H1h*. Additionally, gender differences in overall network density remained minimal across different levels of market participation ($\beta M_{woman-man} = 0.01$, 90 % CI = [−0.08, 0.10]; Fig. 3, Fig. S2 and Table S4), supporting our expectation in *H1j*.

4.2. Gender-specific effects of post-marital residence pattern (H2)

4.2.1. Biological kin density

In matrilocal residence pattern, women exhibited higher biological kin network density than men ($\beta M_{woman-man} = 0.67$, 90 % CI = [0.44, 0.90]; Fig. 4, Fig. S3 and Table S5–6), in line with *H2a*. Similarly, in bilocal residence pattern, women also showed higher biological kin density compared to men, although the increasing trend was less than that in matrilocality ($\beta M_{woman-man} = 0.41$, 90 % CI = [0.15, 0.68]; Fig. 4, Fig. S3 and Table S5–6), supporting *H2e*. In contrast, under patrilocal arrangements, women's biological kin density did not significantly

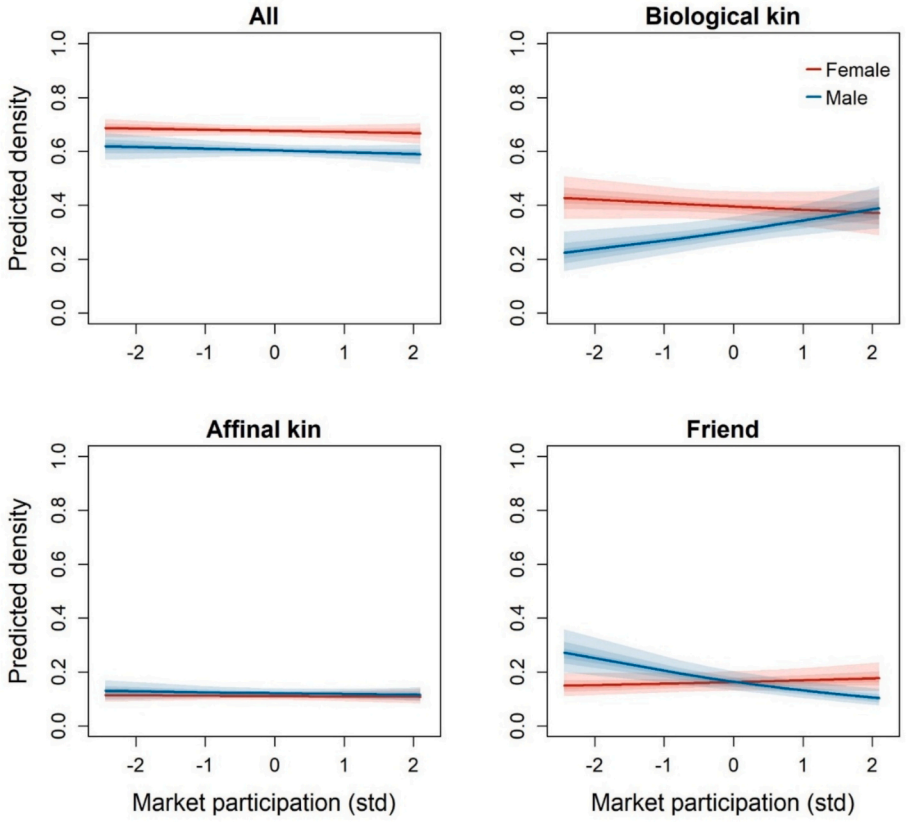

Fig. 3. Four types of predicted ego-network density across gender and market participation. Red indicates women and blue indicates men. The solid line represents the posterior mean prediction, while the shaded areas indicate the 30th, 60th, and 90th percentile credible intervals of 6000 predictions.

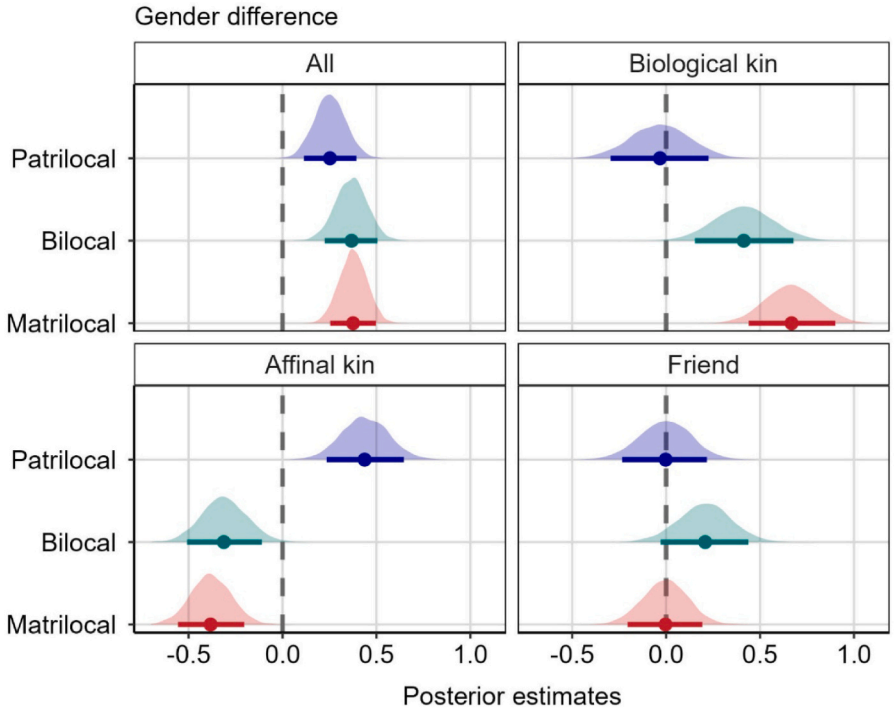

Fig. 4. Gender difference (mean difference in $\boldsymbol{\beta R}$ values comparing women's to men's) in four types of ego-network density by residence and gender. Blue indicates patrilocal, green indicates bilocal and red indicates matrilocal. Points represents the mean estimated gender differences and error bars represents 90th percentile credible intervals of 6000 estimates.

differ from men's ($\beta M_{woman-man}$ = −0.03, 90 % CI = [−0.30, 0.23]; Fig. 4, Fig. S3 and Table S5–6), consistent with *H2c*.

4.2.2. Affinal kin density

In matrilocal residence pattern, women exhibited lower affinal kin network density than men ($\beta M_{woman-man}$ = −0.38, 90 % CI = [−0.56, −0.20]; Fig. 4, Fig. S3 and Table S5–6), in line with *H2b*. A similar pattern was observed in bilocal residence pattern, where women also showed lower affinal kin density than men ($\beta M_{woman-man}$ = −0.31, 90 % CI = [−0.51, −0.11]; Fig. 4, Fig. S3 and Table S5–6), inconsistent with *H2f*. Conversely, under patrilocal arrangements, women displayed higher affinal kin density than men ($\beta M_{woman-man}$ = 0.44, 90 % CI = [0.23, 0.65]; Fig. 4, Fig. S3 and Table S5–6), supporting *H2d*.

4.2.3. Friend density

In both matrilocal and patrilocal residence patterns, women's friend network density did not differ from that of men's (matrilocal: $\beta M_{woman-man}$ = −0.00, 90 % CI = [−0.21, 0.19]; patrilocal: $\beta M_{woman-man}$ = −0.00, 90 % CI = [−0.23, 0.22]; Fig. 4, Fig. S3 and Table S5–6), in line with *H2g*. In contrast, under bilocal residence, women exhibited higher friend density than men ($\beta M_{woman-man}$ = 0.21, 90 % CI = [−0.03, 0.44]; Fig. 4, Fig. S3 and Table S5–6), inconsistent with *H2g* where we expected no gender difference in friend density under bilocality.

4.2.4. Overall density

Across all three post-marital residence patterns, women consistently exhibited higher overall network density than men (matrilocal: $\beta M_{woman-man}$ = 0.38, 90 % CI = [0.25, 0.50]; patrilocal: $\beta M_{woman-man}$ = 0.25, 90 % CI = [0.11, 0.39]; bilocal: $\beta M_{woman-man}$ = 0.37, 90 % CI = [0.22, 0.51]; Fig. 4, Fig. S3 and Table S5–6), supporting our expectations in *H2h*.

5. Discussion

Here we investigate gendered social strategies in a Tibetan population undergoing a transition from traditional agriculture and pastoralism to wage-labour economies, accompanied by shifting inheritance systems from female-biased to gender-neutral. Using data from 1169 married women and men across 14 Tibetan villages, we developed Bayesian models to analyse the scale and composition of ego-networks. To capture the structural nuances of ego-networks, we differentiate between biological kin, affinal kin, and friends. Our analyses test how gendered social strategies are shaped by: (i) participation in market activities, which redefines gender roles and labour division, and (ii) post-marital residence patterns, which structures kin access and bargaining power.

Our findings reveal distinct social strategies adopted by women and men during economic transitions. As men increase participation in market activities, their local ego-networks are more kin-centred, strengthening biological kin ties at the expense of loosening friend ties. While this reduction in local friendships may be partially compensated by forming ties in external markets, the broader pattern suggests a strategic reorientation toward kin-based support. The rise of market economies, accompanied by rapid technological advancement, has profoundly transformed the ways people interact, shifting from dependence on face-to-face contact to communication through digital means (Killian & McManus, 2015). This offers ways for individuals who frequently engage in market activities to maintain contact and interact with local social partners digitally. Nonetheless, family ties, rooted in long-term obligations and shared identity, remain more resilient to distance and temporal disruption than relationships with friends or acquaintances (Pollet, Roberts, & Dunbar, 2013; Viry, 2012). For individuals heavily participating in external market activities, sustaining local friendships becomes more costly, making kin-based strategies adaptive. Interestingly, strategic shift is adopted solely by men, suggesting a gendered pattern in social adaptation. Men predominantly enter the marketplace, particularly in demand-driven and unstable sectors such as construction and transportation (Zhou, 2010). In response, men tend to favour kin-based reciprocity, concentrating their social investment in relationships that provide greater reliability and long-term security (Hintze, Olson, Adami, & Hertwig, 2015). Prolonged absences from local social life further reinforce the reliance on durable kin ties over friendships that require ongoing investment (Burton-Chellew & Dunbar, 2011).

In contrast, women maintain stable social networks regardless of market participation. Their employment – mainly local, rotational agricultural wage labour (Zhou, 2010), preserves village-level social connections. Women's traditional roles require them to uphold stable familial networks, ensuring access to consistent material and emotional support despite external economic changes (Haller & Höllinger, 1990), significantly influencing reproductive success (Hacker, Helgertz, Nelson, & Roberts, 2021; Hackman & Kramer, 2022; Page et al., 2017, 2022; Starkweather, Reynolds, Zohora, & Alam, 2022). This highlights a feature of modernisation in which women often take on 'double shifts' of paid employment and unpaid caregiving (Lilly, Laporte, & Coyte, 2008). When paid employment does not disrupt women's access to local social circles or their traditional caregiving roles, the structure of their social networks remains largely unchanged. This helps explain why our findings are contrary to previous findings that women exposed to more market participation rely less on kin (Colleran, 2020). The key factor is not market participation itself but whether it alters women's traditional gender roles and access to social partners.

We also find that gendered trade-offs between biological and affinal kin are shaped by dispersal patterns. Biological kin are prioritised when geographically close – women in matrilocal and men in patrilocal contexts. This reflects evolved preferences for kin-directed investment (Hamilton, 1964a, 1964b) to maximise resource stability and reciprocity (Hrdy, 2007; Koster, 2018; Seabright et al., 2022; Thomas, Næss, Bårdsen, & Mace, 2015; Wood & Marlowe, 2013). When proximity to natal kin is reduced, reliance shifts toward affinal kin, as observed in patrilocal women and matrilocal men. Displaced individuals cultivate in-law ties to compensate for reduced natal kin access (Power & Ready, 2019; Seabright et al., 2022). Nevertheless, affinal kin generally serves as secondary sources of support and cannot fully substitute for biological kin (Burton-Chellew & Dunbar, 2011; Power & Ready, 2019). In our study area, where most marriages occur within the same township, both biological and affinal kin remain accessible (e.g., patrilocal women have biological kin in nearby villages). Under these conditions, when social investment in slightly distant biological relatives incurs time and effort costs, in-laws can effectively substitute for biological kin in social interactions. This reflects a bilateral kinship orientation (Gengdengcuo., 2015) in which affinal and biological ties are not sharply distinguished and incorporated into a single cooperative kin network.

Women consistently sustain denser overall ego-networks than men irrespective of residence patterns, though mechanisms by which this advantage is achieved vary depending on post-marital residence pattern. Under matrilocality, women rely primarily on biological kin; under patrilocality, on affinal kin; and under bilocality, on friendships, often at the expense of affinal kin connections. With access to both natal and marital kin, bilocal women face conflicts between biological and affinal kin obligations, hence, their attention and resources can be partially shifted toward non-kin alliances to reduce the costs of managing dual kin obligations. This demonstrates women's adaptive flexibility in structuring social ties to maintain network scales under varying residence constraints. Gendered trade-offs in maintaining biological versus affinal kin networks further reflect complementary inter-sexual strategies: couples coordinate to balance close kin ties with affinal relationships, pooling social capital to achieve mutually beneficial outcomes aligned with their shared goal of maximising reproductive fitness. We highlight our direct inter-sexual comparisons of ego-network structure across residence patterns, addressing gaps in previous research that focused on a single gender (Power & Ready, 2019) or ignored gender

differences (Hruschka, Munira, & Jesmin, 2022).

6. Conclusions

This study demonstrates that in a Tibetan population, gendered trade-offs in ego-network scale and composition are shaped by both economic participation and residential contexts. Market involvement affects the balance between biological kin and friend connections, while post-marital residence determines the relative importance of biological versus affinal kin ties. Our Bayesian analyses reveal that men prioritise kin-centric networks for resource reliability under market pressures, while women sustain stable, dense networks critical for childcare and household resilience. We highlight that participation in market activities does not necessarily weaken kin-centric networks; rather, its impact depends on how it shapes traditional gender roles and access to kin. Residence rules further modulate trade-offs between biological and affinal kin relationships for both sexes: when maintaining distant biological kin is costly, affinal kin effectively substitute, reflecting a bilateral kinship system that integrates both into a cooperative whole. Women's consistently denser overall networks across residence patterns underscores their role as kin-keepers, although the pathways by which this advantage is achieved vary by residence types. Note that our findings primarily reflect gender differences in ego-networks' scale and composition, rather than absolute network size, helping reconcile differences with prior studies showing women's smaller but denser networks versus men's larger, looser ones. These findings offer new insights into how socio-ecological factors intersect with evolutionary principles in shaping human sociality. Future research should extend these models to other cultural settings, incorporate longitudinal data to test social network changes over time, and examine how evolving communication technologies further shape gendered social strategies in a rapidly globalising world.

Data accessibility

Data files and code used to generate analyses and figures are provided on GitHub: https://github.com/9YamingHuang42/Gender-differences-in-ego-nets.

CRediT authorship contribution statement

Yaming Huang: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Gabriel Šaffa:** Writing – review & editing. **Shiting Zhang:** Supervision. **Pengpeng Bai:** Investigation. **Liqiong Zhou:** Investigation. **Gui He:** Investigation. **Ruth Mace:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization. **Juan Du:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Ethics

Ethical approval was granted by Lanzhou University (Reference: EAF2023001). Informed consent was obtained from both the local government and all participants.

Funding

This research was supported by National Natural Science Foundation of China (Number: 32401289). J.D. and R.M. were also supported by European Research Council Advanced Grant (Grant number: 834597). Y.H. was supported by China Scholarship Council (Number: 202306180072).

Declaration of competing interest

We declare we have no competing interests.

Acknowledgements

We sincerely thank the local community members who participated in this study by completing our questionnaires. We are also deeply grateful to our local assistants, Luo Ti, Zhaxiqidan, and their family members, for their invaluable help and support during data collection.

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