Title:

Population structured by witchcraft beliefs.

Authors:

Ruth Mace[$*1,2,3], Matthew G Thomas[*,1,4,5], Jiajia Wu*1,2,3, QiaoQiao He[*2], Ting Ji[*$2,1], Yi Tao[$,2]

*these authors contributed equally to this paper as co-first authors

[$]corresponding authors Ruth Mace. r.mace@ucl.ac.uk

Ting Ji. jiting@ioz.ac.cn

Yi Tao. yitao@ioz.ac.cn

Author affiliations:

1 Department of Anthropology, University College London, 14 Taviton Street, London WC1H 0BW, UK
2 Key Laboratory of Animal Ecology and Conservation Biology, Centre for Computational and Evolutionary Biology, Institute of Zoology, Chinese Academy of Sciences, Beijing 100101, People's Republic of China
3 Lanzhou University, Life Sciences, 222 Tianshui South Rd, Lanzhou, Gansu Province, 730000, PRC
4 Norwegian Institute for Nature Research and Norwegian Institute for Cultural Heritage Research, Fram Centre, Postboks 6606 Langnes, 9296 Tromsø, Norway
5 Norwegian Institute for Cultural Heritage Research, Fram Centre, Postboks 6606 Langnes, 9296 Tromsø, Norway

Keywords

Tag-based cooperation, assortment, partner choice, social networks, spite, witchcraft

Abstract

Anthropologists have long argued that fear of victimisation through witchcraft accusations promotes cooperation in small-scale societies[1]. Others have argued that witchcraft beliefs undermine trust and therefore reduce social cohesion [2]. However there are very few, if any, quantified empirical examples demonstrating how witchcraft labels can structure cooperation in real human communities; nor any estimates of the fitness costs associated with such labels. Here we show a case from a farming community in China where a label '*zhu*' was associated with exclusion from cooperative networks. People labelled *zhu* were thought capable of supernatural activity, particularly poisoning food. The label was usually applied to adult women heads of household, and is often inherited down the female line. We find that those in *zhu* households were less likely to give or receive gifts or farm help, or have sexual partners or children, with those in non-*zhu households*. The tag *zhu* was associated with reduced biological fitness. However those in *zhu* households did preferentially help and reproduce with each other, which mitigated the costs of this tag. Whilst the tag is common knowledge to other villagers, and used in cooperative and reproductive partner choice, we found no evidence that this assortment was based on cooperativeness or quality. We favour the explanation that stigmatisation originally arose as a mechanism to harm female competitors. Once established, fear that the trait is transmissible to others helps to maintain a population structure based around this arbitrary tag and thus helps explain the persistence a deep-rooted cultural belief.

Accounts of witchcraft beliefs have been documented from all world regions, often in those communities where formal legal systems were weak or absent [3]. Conceptions of witchcraft around the world are heterogeneous, but share some similarities: notions of poisoning are common [4,5]; supposed witches were often conceived of as greedy [6] or beautiful [7] or those that stand out in any way; accusations arise in the context of attribution of blame for illness, death or other misfortunes [1,8], and could arise within families[9], such as between co-wives [10], or from the wider community [8,9]; harm could often be cured through payments or medicines[1]; and in some societies the label could lead to violent punishment [9]. It was common for women or children to be accused, especially older women [2]. In some cases, witchcraft accusations appear to be a form of extrajudicial punishment or scapegoating of marginal individuals, often family members[9]. In some cases the risk of being labelled as a witch appears heritable[1,11]. Spiteful witchcraft accusations could arise for revenge, or due to reproductive competition, or indeed any form of competition for resources.

During the course of fieldwork on cooperative networks in a rural population in southwestern China, we became aware that some individuals were stigmatised with a cultural label '*zhu'* or '*zhubu*' . The label is related to a type of taboo associated with fear of food poisoning. Accounts of z*hu* mentioned a notion of infection that has some parallels with biological parasitism.. Which households were stigmatised in this way was common knowledge and people sometimes advised us against eating in *zhu* households. Women were the most likely to be considered capable of poisoning, with men most likely to be cited as victims [12]. Accounts suggested accusations could spread quickly through villages [13]. '*Zhu', 'Zhubu' or 'Du'* is sometimes translated as 'poison giving' or witchcraft [12],. In much of the world, witchcraft accusations appear to be a

form of extrajudicial punishment or scapegoating of marginal individuals, usually family members[9]. [1]Here, the label put stigma on to the whole household and was likely to have been inherited [7,12]. There are also accounts of households becoming contaminated with zhu through bringing valuable, metal objects into the house[13]. However the origin of both historical or more recent accusations is unclear, even to those who are the subject of such rumours[11] . This status was sometimes reported to be a misfortune rather than something that was the fault of the stigmatized individuals. During communal labouring on farms, the farm owner usually provides meals for those who work on their farm all day. Thus communication about a reputation for food poisoning relating to a particular household would be detrimental to recruiting help on that farm, or indeed to those from that household being considered suitable partners of any kind.

In accounts of this phenomenon in the ethnographic literature of the region, the label 'zhu' in this group, the Mosuo, appears similar to something referred to as 'Du' or 'Gu' [12], and to the label 'chao pu xi' in the neighbouring Naxi [7]. A similar phenomenon has also been described in the Qiang, also in southwest China; there accused women, said to be outsiders and/or those considered beautiful, are described as 'poison cats' and shunned [5]. There are also strong similarities with 'poison givers' in Bhutan[11]

[11] and with some concepts of witchcraft in Tibetan Nyimba [4].

Such tags could be attached to significant sections of the population, contradicting some accounts suggesting the phenomenon is marginal. There are historical accounts of the denouncing of some women as dangerous in several Indian, Thai and Chinese societies occurring on a very large scale. Whole villages of those labelled '*pippa*' were described in the Yuan in northern Thailand and in the Dai in Yunnan, China [7]. This is thought to have arisen in the context of patriarchal powers attempting to realign gender relations away from more female-centred or matrilineal cultures [7]. In Sichuan, China, the Naxi, are thought to have switched from a matrilineal to a patrilineal social structure after coming under the control of patrilineal Han in the 18th century. There were accounts of large numbers of women being denounced as '*chao pu xi*' or 'keepers of evil spirits' at that time. The introduction of the Confuscian ideals of female obedience to men was said to be associated with large numbers of female suicides in the region, some accounts suggesting many suicides were daughters of the denounced women [7] . One account suggests Mosou households can rid themselves of the label by changing their family name from their matrilineal to their patrilineal name[14] . Accounts of the Mosou acquiring the label *zhu* or *du* by bringing valuable metals into the household , possibly from other ethnic groups [7,13], has parallels with the process of acquiring the label '*pippa*' in the Dai of Yunnan [7]. Such tags appear to have been used as mechanisms for levelling or appropriating wealth from women **[7,12-15].**

Who cooperates with whom?

In 2012 we collected data on cooperation between households by collecting social networks from five villages in rural southwestern China, comprising about 800 households (see SI). Social networks were measured in three ways. Demographic data

enabled us to identify kinship networks between all households, including where children were living (in the case of this population fathers often do not live with their children due to the prevalence of duolocal residence [16]; see SI). We also played some simple economic gift games with a sub-sample of households, in which individuals were allowed to give gifts of money (provided by us) to up to three adult individuals resident in any other household in the study site (see SI). And finally we collected data from working groups on a sub-sample of farms, during planting and harvest time, to identify who was helping whom in their fields. This resulted in four measures of the relationships between households: biological relatedness between households: whether any-one in one household had a sexual partner in another household, whether any-one gave a gift in a gift game to another household and whether they helped on another household's farm. We also played a simple donation game, where we gave each person 10 yuan that they could divide between themselves and an anonymous person in the same village. This we used as a general measure of within-village cooperativeness.

After collecting all the social network data and economic game data, we asked a few informants from the villages to identify any household that people considered *zhu* in their locality. Those labelled as such comprised 13.7% of all households. Data on all the four measures of social connection (sexual partnerships including marriage, children, farm help and gifts) indicated that having the label *zhu* predicted that household would be somewhat excluded from mainstream social networks. The clustering shown in Fig 1 shows that *zhu* households often clustered together in small networks (up to about 10 households at most) or dyads with each other. This was especially true with respect to reproductive partnerships and children (Fig 1d). Fig 2 shows the results of a permutation test run on each of these networks, which shows that the probability of this level of assortment occurring by chance is overwhelmingly unlikely in all four networks. Whilst *zhu*-labelled households received no less help on their farm and only slightly fewer gifts in the gift game overall (Table S1), it is very clear that the gifts and help they did receive were more likely to be from other *zhu* households (Fig 1,2, Table S1, S2). There is even stronger assortment with respect to reproductive behaviour; very few *zhu* had any sexual partners or children in non-*zhu* households (Fig 1, Fig 2, Table S1, Table S2).

Thus the information we had received from some villagers clearly had salience across the population. Those in households stigmatised by this reputation for poisoning were surviving in the community by assorting preferentially with each other, both in terms of whom they decided to help and give gifts to, and whom they chose as partners and spouses (Fig 2, Table S2). Biological relatedness was the main factor that mediated social networks extending between households tagged as *zhu* and those that were not (Table S2c).

This self-assortment appeared to counter some of the costs that would otherwise be caused by exclusion from mainstream social networks. Those households with the tag *zhu* were not necessarily poor; in fact they were ranked as slightly wealthier than average (Fig S1; Table S4), (it should be noted that land was redistributed according to household size soon after the formation of the People's Republic of China, so historical differences in land-holdings did not persist into current generations). There is very limited dispersal from their natal village for *zhu* and non-*zhu*: 82.6% of non-*zhu* and

82.3% of *zhu* either never left their natal household or had dispersed to another household within their birth village (Table S5). In most respects, the household characteristics of those labelled *zhu* are not atypical of other households in the population. The households reported to contain *zhu* were not necessarily clustered geographically (see Table S6). Nor was there any evidence from the donation game that they were any less cooperative toward the village than any other villagers; the distribution of donation sizes were almost identical between those with and without the tag (Table 2).

Almost all women in the population had children (Fig S3), although government legislation in the 1980s restricted fertility to 3 births per women, which is reducing variance in reproductive success. However Fig 3 shows that female heads of *zhu* households have lower than average reproductive success. This suggests that their exclusion from mainstream social networks was costly to fitness (Table S6). Although it is also possible that those with low reproductive success could have been more likely to attract the label. Males in *zhu* households did not appear to suffer significant fitness costs from being in households tagged with this label (Table S7). Age at first birth was not associated with the label *zhu* (Table S8). It is a possibility that in many cases the accusation against women occurred when already adult, (a woman in Bhutan reports how she was ostracised for being a 'poison giver' in middle age, and she notes that her mother had suffered the same fate). The harmful effects of exclusion may only take effect later in life (as *zhu* were considered to be more dangerous when older). It appears that assortment with other tagged individuals clearly mitigated the costs of ostracism by those who were not tagged.

As our data on this cultural tag are not longitudinal, we are unable to verify the claim that this form of stigmatisation was inherited over generations (in the sense of some mother/daughter correlation in the risk of acquiring the label); but the strong reproductive assortment suggests this is likely. *Zhu* were in fact more closely related to each other than they were to non-*zhu*. Within villages, mean (SD) genealogical relatedness between *zhu* was r=0.152 (0.163) and genealogical relatedness between non-zhu was r=0.125 (0.144), whereas average genealogical relatedness between *zhu* and non-*zhu* is r=0.083 (0.096). Whilst they might be considered as an out-group, there is no evidence that *Zhu* migrated in from elsewhere, at least in recent times, nor that they are more likely to have moved villages (Table S4).

Discussion

This study presents the first quantified empirical demonstration of assortment into cooperative networks on the basis of a label associated with supposedly harmful supernatural powers, and of the fitness consequences associated with this label. Such tag-based assortment can have evolutionary consequences when, by making competitors appear as suitable or unsuitable as partners, their fitness can be enhanced or harmed. In this case, the tag was used for avoiding cooperation with differently tagged individuals, especially women, including avoiding reproducing with them. However there were enough tagged households for them to ameliorate the costs by

helping each other and assorting into their own cooperative and reproductive networks. Whether reputational damage through stigmatization is a mechanism for enforcing norms, or whether it is simply the harming of competitors, or both, it does appear to be a mechanism by which the population is structured. Thus we illustrate how mutually cooperative groups or sub-populations can arise on the basis of assortment on an arbitrary cultural tag.

Many of the characteristics of being labelled as scapegoats for harmful events, as described in the abundant ethnographic literature on witchcraft accusations, find parallels with social evolutionary theories for maintaining cooperation through the strategic use of cooperation and punishment. Some theories and laboratory experiments suggest cooperation between unrelated individuals might emerge due to assortment on cooperativeness [17-20]. One study claims that cooperators assort in a mobile forager population [21]; but spatial assortment might be easier in nomadic groups than in settled farmers. Third party punishment involving reputational damage to defectors might be more prevalent in sedentary populations, where the option of 'walking away' [22,23] from uncooperative neighbours is not a readily available strategy. There is some evidence that participation in collective tasks for the public good can enhance the social networks of more cooperative farmers [24]. However, we find no evidence in this study, either from real world behaviour or economic games, that those labelled *zhu* are uncooperative. Hence our study, whilst showing strong evidence for assortment on the basis of a tag, finds no support for the hypotheses that assortment is based on cooperativeness; so we cannot claim that this harmful tag is punishment for selfishness.

We favour competition as a more plausible explanation for the origin of cultural tags that stigmatize certain individuals or households. A comparative study in Africa suggests that societies where there are strong witchcraft beliefs report low levels of trust in a questionnaire; witchcraft beliefs undermine inter-household cooperation rather than promote it [2]. This view fits with anecdotal accounts of fear of witchcraft accusations disrupting cooperation, which can undermines participatory approaches to poverty alleviation [25]. We have shown previously, in this region, that there are lower levels of cooperation with other villagers in those societies with low rates of female dispersal, such as this one, when compared with those societies in the region where female dispersal rates are higher [26]. Societies with low dispersal also have higher relatedness between households. Qiang villages where witchcraft beliefs have been described as prevalent are also characterised by low dispersal [5]. Thus, in sedentary groups, where dispersal is low and relatedness high, competition between households may be more intense and more likely to generate attempts at reputational damage through the use of harmful cultural tags. Our finding that this label is more likely to fall on slightly wealthier and female-headed households fits with anecdotal accounts from other populations of accusations arising out of jealousy or spite, directed particularly at women[7,25]. The difficulty in establishing the precise origin of rumours may make the process of stigmatizing others relatively low cost to accusers. The ecological conditions in which this cultural tag has persisted has some features predicted to enhance the possibility that spiteful behaviour can evolve [27]. It is also possible that villages with some residents that were feared for having dangerous powers may have gained some

protective advantage against outsiders [5]; that could be one reason why ostracised sub-groups, whilst shunned by the majority, were nonetheless tolerated within the community. One origin myth describes some Mosuo travelling to the Naxi to gain this dangerous power as they thought it might be useful in conflict with enemies [7].

Whilst one would expect cultural beliefs relating to supernatural powers to decline with education, witchcraft beliefs in Africa have been shown to be surprisingly resistant to 'modernisation' [2]. It was clear from our observations that many villagers did fear tagged individuals as a risk of contamination and avoided visiting their houses; whilst other villagers said they did not believe this. However, in any cultural system where a harmful tag is considered able to contaminate others, even those who do not believe tagged individuals to be dangerous might nonetheless incur costs were they to assort with tagged individuals, as they would themselves then run the risk of ostracism. In other words, 'non-punishers' may be punished, so long as at least some of the population hold these beliefs. Third party punishment can itself act as a signal[28] , in this case of not being part of the stigmatised group. This may explain why such deep-rooted cultural beliefs persist and can continue to structure populations, even in the face of modernization.

Experimental Methods

Data collection

Research ethics were approved by both University College London research ethics committee (ref 0449.002) and the Chinese Academy of Sciences, Beijing (ref IOZ12015).

Demographic and socio-economic surveys were conducted in five villages in Sichuan province during 2012. One adult was interviewed on behalf of all household members about details including name, age, sex, ethnic group, names of spouses and parents. Pedigrees were created by linking each person in the census to their mother and father, which was then used to calculate genealogical relatedness between individuals. Relatedness between households was the mean relatedness between all the individuals in the alter and ego households (see SI).

In 2013, participants played a gift games in which they gave gifts to other individuals. Participants were endowed with 15 yuan (equivalent to pay for a few hours work locally), which they could give—in five yuan denominations—to between one and three recipients of their choice who were resident in any of the study villages. Then the participants played a within-village donation game in which they were given 10 yuan to split between themselves and another anonymous, randomly allocated player from their village.

Spot observations of people working on farms were conducted during the planting seasons of 2011 and 2012 and the harvest season of 2012. Locations were randomly sampled within the study villages, giving unbiased, although incomplete, coverage.

Wealth ranking of households was conducted by 1-3 key informants in each village. We presented them with cards representing the heads of each household; they then divided the cards into three piles: rich, medium, and poor. The villagers further divided 'medium' into another four piles, leaving a total of 6 piles of households: very rich (1) to very poor (6). The people who did the wealth ranking were usually current or former heads of that village who were familiar with every household (note that wealth ranks can only be interpreted within the context of each village).

Whether a household was considered *zhu* by the community was common knowledge in every village and those considered *zhu* in each local area were identified by some-one resident in that area.

Statistical analyses

We used Zero-Inflated Poisson (ZIP) regressions to model the effect of being labelled a *zhu* house on the amount of help observed on its farm and the number of gifts received from other households (both measures of in-degree). ZIP models account for over-dispersion—in this case, an 'excessive' number of households with in-degree of zero—by assuming there are two 'types' of household: households whose in-degree is generated by a Poisson process, and households with a zero probability of having in-degree > 0 (i.e. households for which no farm work was observed due to the random sampling of households). ZIP models thus estimate a Poisson model for the count data alongside a logistic regression predicting the log odds that a household had in-degree = 0; both are interpreted in the standard manner. The ZIP models controlled for household size, wealth rank and sex of the household head, and included village as a categorical variable. This analysis did not include village A because only a few observations were made there and none included helping on *zhu* farms. This left n = 660 households.

We used multilevel Poisson regressions to analyse the relationship between presence or absence of the *zhu* label and reproductive success (RS), measured as number of living children, with varying intercepts for villages (for Fig 3, Table S6-S8). These models were fitted separately on female and male household heads (n = 352 and 379, respectively). We fitted Cox regressions to determine the effect of being known as *zhu* upon age at first birth (AFB). Models were fitted separately on adult (aged 15 years or older) females and males (n = 1,625 and 1,641, respectively). We used logistic regression to examine what factors predicted if a household was labelled *zhu* or not (n = 514) Table S. Note that this is a model of households, unlike the RS and AFB models, which were models of individuals.

For the RS, AFB and ZIP analyses, we used a model selection approach on sets of a priori candidate models, using model averaging as appropriate[29]. See SI Tables for further information.

To measure assortment based on the *zhu* label, we calculated assortativity coefficients[30] on the farm labour, gifts, partners and children networks. We ran permutation tests to generate a null distribution of assortativity coefficients by simulating 1,000 random networks with the same properties as the real networks: i.e. the same numbers of gift

givers or farm helpers, the same number of connections to recipient households, and the same proportion of people labelled *zhu* in the networks.

We used 'join count' statistics to examine whether *zhu* houses were physically clustered in the study villages. Join counts test the extent to which the occurrence of *zhu* households at spatially adjacent locations is due to chance[31].

Analyses were conducted in R 3.3[32] . The packages used are given in the SI.

Contributions of authors.
Conceptualisation, RM, JJW, QQH, JT and YT; Methodology, RM, MGT, JJW, JT, YT; Software, MGT; Investigation, JJW, QQH, and JT; Data curation, JJW, QQH, JT and MGT ; Formal analysis; MGT and JJW; Visualisation, MGT; Writing – original draft, RM; Writing – review and editing, RM, MGT, JJW, JT; Supervision, RM and YT; Funding acquisition, RM, QQH, JT, YT.

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Data availability: raw data is not available due to the need to maintain anonymity of households, but abridged data is available on request to the authors.

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Fig. 1. Networks of observed (a) farm work, (b) gifts, (c) partners, and (d) children living in other households for one of the study villages. Nodes represent households with a tag ('*zhu*'; squares) or not (circles). Nodes are coloured by cluster membership as assigned through an edge-betweeness algorithm (a and b) or 'fast-greedy' algorithm (c and d). Arrows show links between household for each of the four networks. Instances of farm help depended on the amount of fieldwork conducted per village and gift-giving depended on whether households chose to participate in the games; so the absence of either should not be taken as absence of cooperation. Networks were produced using the igraph package in R 3.3, with a Fruchterman-Reingold layout. Spatial location in the figures is arbitrary and does not represent spatial location in the village. Individual households not put in clusters are omitted from these figures.

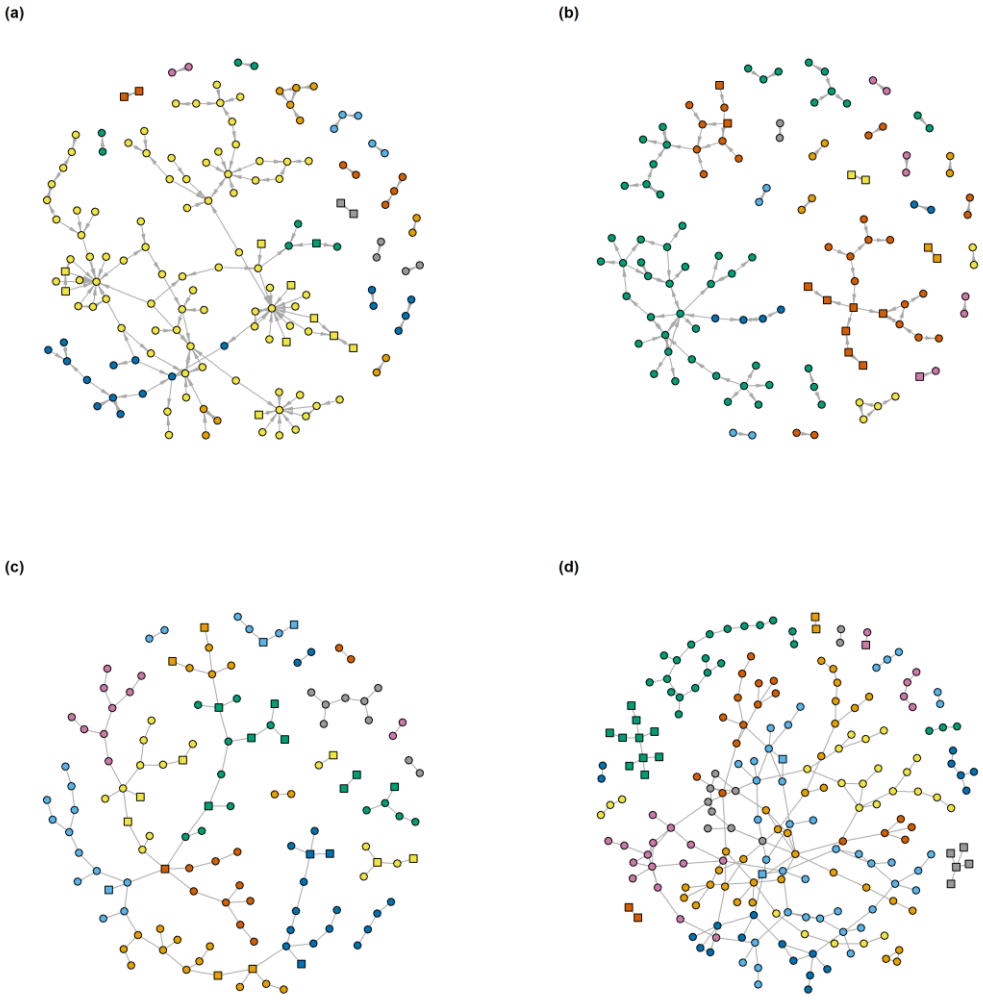

Figure 2

Assortativity on whether households contain *zhu* for the four social networks (see Table S3 for sample sizes). Red diamonds show observed assortativity coefficients. Boxplots represent null distributions generated from a permutation test of 1,000 random networks with the same numbers of nodes, edges and *zhu* labels as in the observed networks. Thus the probabiity of the observed levels of assortment being random is clearly $p<<0.001$ for all four measures.

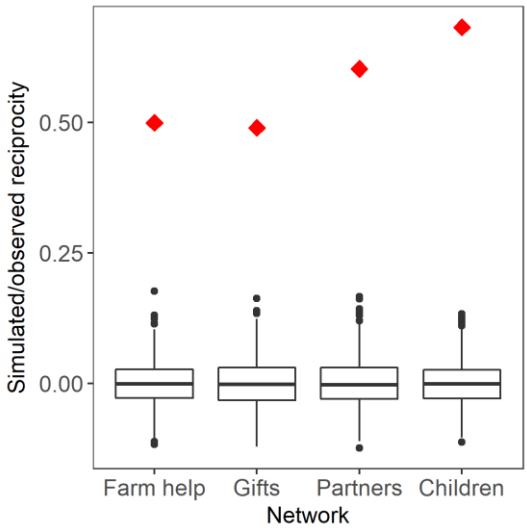

Fig. 3. Fertility of household heads. Model-averaged parameter estimates with unconditional 95% confidence intervals predicting number of living children for adults aged 15 and over, including (**A**) female heads of households (*n* = 363) and (**B**) male heads of households (*n* = 394). In all cases, the response variable was number of living children at the time of the 2012 census

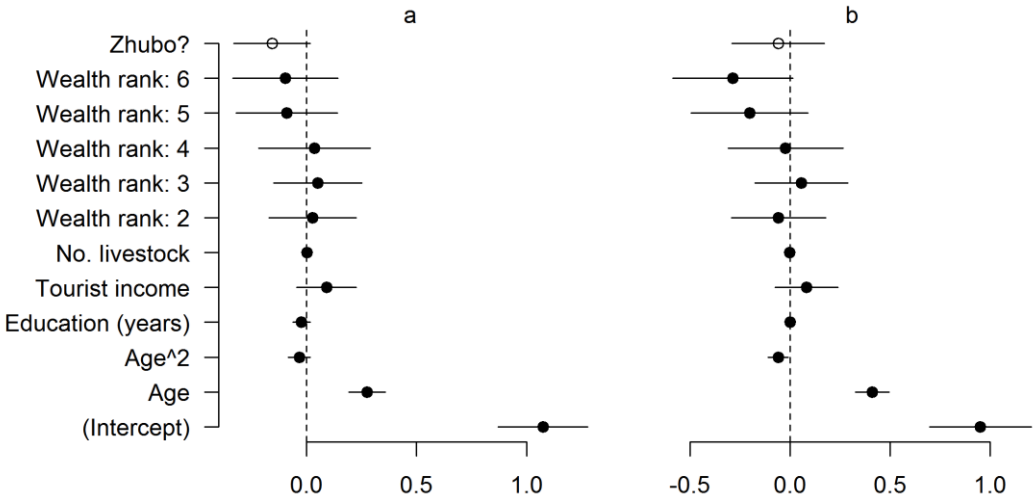

Table 1. Donations to an anonymous villager in a simple economic game.

Each player was given 10 Yuan. They decided how much they would like to keep and how much to give to an anonymous, randomly selected villager. Using Wilcoxon rank sum test to compare player's offer to an anonymous partner between individuals from zhu and non-zhu households, we found that there is no difference between them (N=564, W = 18903, p-value = 0.7282).

Offer	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Sum**
Non-zhu	19	4	37	25	44	178	35	10	69	16	47	484
Zhu	3	1	4	4	9	27	10	2	8	3	9	80
% offers												
Non-zhu	4	1	8	5	9	37	7	2	14	3	10	100
Zhu	4	1	5	5	11	34	13	3	10	4	11	100