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# Human Nature

## Does kin-selection theory help to explain support networks among farmers in South-Central Ethiopia? --Manuscript Draft--

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<b>Abstract:</b>	<p>Social support networks play a key role in human livelihood security, especially in vulnerable communities. Here we explore how evolutionary ideas of kin selection and intra-household resource competition can explain individual variation in daily-support network size and composition in a South-Central Ethiopian agricultural community. We consider both domestic and agricultural help across two generations with different large-wealth transfer norms that yield different contexts for sibling competition. For farmers who inherited land rights from family, first-borns were more likely to report daily support from parents and to have larger non-parental kin networks (n=180). Compared with other farmers, first-borns were also more likely to reciprocate their parents' support, and to help non-parental kin without reciprocity. For farmers who received land rights from the government (n=151), middle-born farmers reported more non-parental kin in their support networks compared with other farmers; non-reciprocal interactions were particularly common in both directions. This suggests a diversification of adult support networks to non-parental kin, possibly in response to a long-term parental investment disadvantage of being middle-born sons. In all instances regardless of inheritance, last-born farmers were the most disadvantaged in terms of kin support. Overall, we found that non-reciprocal interactions among farmers followed kin selection predictions. Direct reciprocity explained a substantial part of the support received from kin, suggesting the importance of the combined effects of kin selection and reciprocity for investment from kin.</p>	
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## **Does kin-selection theory help to explain support networks among farmers in South-Central Ethiopia?**

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Key words: support network, social capital, birth order, kin selection, reciprocity, inequalities

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Conflict of interest: the authors declare that they have no conflicts of interest.

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**Abstract**

Social support networks play a key role in human livelihood security, especially in vulnerable communities. Here we explore how evolutionary ideas of kin selection and intra-household resource competition can explain individual variation in daily-support network size and composition in a South-Central Ethiopian agricultural community. We consider both domestic and agricultural help across two generations with different large-wealth transfer norms that yield different contexts for sibling competition.

For farmers who inherited land rights from family, first-borns were more likely to report daily support from parents and to have larger non-parental kin networks (n=180). Compared with other farmers, first-borns were also more likely to reciprocate their parents' support, and to help non-parental kin without reciprocity.

For farmers who received land rights from the government (n=151), middle-born farmers reported more non-parental kin in their support networks compared with other farmers; non-reciprocal interactions were particularly common in both directions. This suggests a diversification of adult support networks to non-parental kin, possibly in response to a long-term parental investment disadvantage of being middle-born sons. In all instances regardless of inheritance, last-born farmers were the most disadvantaged in terms of kin support.

Overall, we found that non-reciprocal interactions among farmers followed kin selection predictions. Direct reciprocity explained a substantial part of the support received from kin, suggesting the importance of the combined effects of kin selection and reciprocity for investment from kin.

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4 **Introduction**  
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7 Social capital, alongside natural capital, physical or produced capital, and human capital, is an important  
8 part of sustainable development. Because social capital can be defined as “the features of social  
9 organization, such as networks, norms, and social trust that facilitate coordination and cooperation for  
10 mutual benefit” (Putnam 2000), social capital, by virtue of its collective nature, has an important influence  
11 on resource sustainability at a population/community level (Pretty 2003). In developing countries that lack  
12 resource access, infrastructure, or social policies to support vulnerable communities, networks have been  
13 shown to not only provide the social insurance and safety nets that foster resilience and recovery in times of  
14 hardship (Fafchamps and Lund 2003, Caudell, Rotolo and Grima 2015), but also to build human capital,  
15 material capital, and improve community well-being (Narayan and Pritchett 1999, Aldrich 2012, Aldrich  
16 and Meyer 2014).  
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19 Using an evolutionary perspective, this research aims to investigate daily support networks as strategies  
20 used by individuals and families in rural South-Central rural Ethiopia and to identify the most vulnerable  
21 among them. This agricultural population is largely dependant of land for cereals and vegetables  
22 production. Personal support networks are comprised of kin and non-kin supporters, which is an important  
23 distinction from an evolutionary perspective: kin-selection theory predicts that kin will allocate resources to  
24 their relatives in a manner that enhances transmission of their common genes (Hamilton 1964). In other  
25 words, kin support is an investment in one’s own fitness, either directly (via direct descendants) or  
26 indirectly (in other kin), where fitness is defined as the survival of the biological lineage across generations,  
27 or the number and quality of descendants achieved by accumulation of social, material, and biological  
28 capital. According to kin selection, individuals face trade-offs in their effort to acquire finite resources;  
29 thus, they make decisions (consciously or not) about resource allocation in their support networks  
30 according to genetic relatedness (Hamilton 1964). Recipient characteristics other than genetic relatedness  
31 also influence resource allocation decisions, such as reproductive potential and survival rate, which are  
32 shaped by gender (Trivers 1972, Trivers and Willard 1973) and birth order (Clutton-Brock 1984; Hrdy and  
33 Judge 1993). In theory, any individual characteristics influencing reproductive potential and survival rate  
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4 might possibly influence kin investment decision. In rural Ethiopia, land access influences livelihood  
5 security and reproduction and is, thus, probably important to kin investment patterns.  
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9 Parental investment, which is the most fundamental kin investment, significantly influences the fitness of  
10 parents and children (Trivers 1974); it includes various investments, from parental care and education  
11 (Gibson and Sear 2010, Gibson and Lawson 2011), to wealth transfers during life and at death (Judge and  
12 Hrdy 1992, Hrdy and Judge 1993, Gibson and Gurmu 2011). Among the various land owner societies  
13 facing limited resources around the world, a gradient of wealth transfer systems has evolved from biased  
14 multigeniture (Clarke and Low 1992, Towner 2001, Faurie, Russel and Lumma, 2009, Gibson and Gurmu  
15 2011) to unigeniture (Boone 1986, Hrdy and Judge 1993, Voland and Dunbar 1995, Strassman and Clarke  
16 1998), favouring some children over others, possibly to ensure lineage survival across generations and/or to  
17 avoid capital fragmentation and economic decline within very few generations. As a consequence, favoured  
18 children enjoy a better resource status and, possibly, might enjoy larger kin support because they represent  
19 safer investment for the future of the lineage compared with their sibling.  
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32 Research on parental investment, has yielded variable and occasionally conflicting results about birth  
33 order (Draper and Hames 2000, Faurie, Russel and Lumma, 2009, Stanton et al. 2014). In Ethiopia, a first-  
34 born son advantage for agricultural productivity, marriage, and reproductive success has been shown in  
35 the context of family land transfers but was not observed when no family land transfers occurred (Gibson  
36 and Gurmu 2011), suggesting that inequalities in intra-household material resource access for brothers  
37 only arise in the context of competition for limited resources.  
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46 The importance of kin selection and reciprocity for cooperation with kin is discussed in the literature  
47 (Clutton-Brock 2009, Jaeggi and Gurven 2013, Taborsky 2013, Carter and Wilkinson 2013). Some  
48 individuals might actively engage in network manipulation by seeking extra interactants to secure  
49 additional support; one way to lower the cost for potential interactants is through reciprocity, which lowers  
50 the costs for interactants (Trivers 1971).  
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57 Herein, we investigate whether patterns in the kin and non-kin make-up of adult children's support  
58 networks, reinforces or offsets patterns of material resource access for two generations of Ethiopian  
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4 agriculturalists with different large-wealth transfer patterns.  
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7 The Ethiopian context offers a unique setting to look directly at the effects of intra-household competition  
8 and kin investment. Ethiopia's recent political past, including the Marxist revolution that led to land  
9 confiscation and subsequent redistributions in 1975, 1988, and 1990 in this agricultural area, provides a  
10 natural experiment to study two cohorts of farmers that received land either from family transfer (inheritor  
11 group) or from government (redistribution group). In the study community, family land transfers primarily  
12 concern male farmers. Even the successive government redistributions targeted male heads of household.  
13 Nowadays, by law, all children, females and males, have the right to claim their share of inheritance. In  
14 practice, most families provide land to their sons and provide other type of goods to their daughters, who  
15 marry out their communities. Because of rapid population growth and limited land availability, farmland is  
16 becoming a scarce resource in this part of Ethiopia, so we expect this to increase the investment biases  
17 predicted by kin selection, but in different ways for the two farmer groups.  
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30 Farmers in the younger group became adults after the government redistribution programs ended; thus,  
31 their land access was completely determined by their parents, they received farmland before or for their  
32 marriage and received or might receive additional land upon their parents' deaths. Previous research  
33 suggests a multigeniture with a first-born son advantage for the youngest generation (Gibson and Gurm  
34 2011).  
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40 The oldest group's parents were not permitted to favour any of their sons for large wealth transfers because,  
41 in theory, all sons received land of equal size and quality from the government; furthermore, this sweeping  
42 policy likely affected other types of parental and kin investment besides wealth transfers. Studies on  
43 parental investment in the context of equal resource access suggest that first and last-born children tend to  
44 be advantaged over middle-born children (Hertwig, Davis and Sulloway 2002), who receive fewer  
45 cumulative investment due to competition with younger and older siblings. Faurie, Russel and Lumma  
46 (2009) corroborated Hertwig, Davis and Sulloway's (2002) finding among sons of rural pre-industrial  
47 Finns: middle-born sons appeared to produce significantly less offspring than first- or lastborn sons.  
48 Concerning relational capital biases, cues from studies of Western societies suggested that disadvantaged  
49 children might offset their parental-investment disadvantage by manipulating their networks through  
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4 diversification of support including other kin (Salmon and Daly 1998, Rhode et al. 2003,) or non-kin  
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6 (Salmon and Daly 1998, Salmon 2003).  
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9 Thus, to understand the complexity of support patterns, it is important to discriminate among sources of  
10 support (e.g., parents, non-parental kin, and non-kin), to identify the directions of support interactions (non-  
11 reciprocal or reciprocal), and to discriminate between birth order and intra-sex birth order. Finally, the daily  
12 agricultural and domestic support networks of household heads should be an accurate proxy for measuring  
13 social capital in a mixed economy where cash is not widespread, because such support entails meaningful  
14 energetic and material costs and has direct impacts on household wellbeing. Because this study population  
15 is patriarchal, patrilineal, and patrilocal, with strong gender differences in socio-economic activities that  
16 could affect individuals' social networks, we focused on the support networks of male heads of household.  
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26 This paper aims to test two sets of evolutionary predictions about daily support network size and  
27 composition among Ethiopian farmers: 1) Daily support networks will vary according to sibling  
28 competition, with different birth-order biases for the generation groups. 2) Farmers' daily support networks  
29 will pattern in a way that is consistent with reciprocity and kin-selection theory.  
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35 Prediction 1: We will observe birth-order biases in support network size and composition  
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37 At the outset, we expect to observe two scenarios regarding daily subsistence and domestic support:  
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- 40 1. In the context of limited resources, first-born sons might interact more with parents and with non-  
41 parental kin compared with other birth-order categories, because, first-born sons represent a less  
42 risky investment for lineage survival (Hrdy and Judge 1993, Gibson and Gurmu 2011). Later-born  
43 sons being disadvantaged in kin interactants, might diversify their networks to include non-kin,  
44 possibly through reciprocity  
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- 50 2. For farmers who received their land from the government without discrimination, first and last-  
51 born sons might have enjoyed extra-parental investment in terms of cumulative investment in their  
52 lifetimes (Kidwell 1982, Sulloway 1996, Hertwig, Davis and Sulloway 2002, Faurie, Russel and  
53 Lumma 2009). If those differences held into adulthood, middle-born sons might still represent  
54 worthwhile investment for non-parental kin, especially if they are more active in diversifying their  
55 networks. They may do this by diminishing the costs of investment for the givers through  
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4 reciprocity (Trivers 1971, Salmon 2003). This strategy would result in middle-born sons having  
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6 larger non-parental kin and non-kin networks compared with first and last-born sons.  
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9 Prediction 2: Variation in farmers' support networks is consistent with reciprocity and kin-selection  
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11 theories

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13 Reciprocity is a strategy by which people obtain greater resource security and social support by  
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15 diversifying their networks and engaging in interactions with more people. However, because of time and  
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17 cognitive constraints (Dunbar 2008) that limit the number of social contacts a person can meaningfully  
18  
19 manage, the benefits of a reciprocal support strategy are limited. We expect that most non-kin interactions  
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21 would be based on reciprocity, while non-direct reciprocity (unidirectional interactions) would be more  
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23 common with kin and even more common with close-kin, according to expected benefits of inclusive  
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25 fitness (Hamilton 1964; Trivers 1972). Kin might constitute an important proportion of men's reciprocated  
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27 social ties, because kin interactants can benefit from both inclusive fitness and reciprocity.  
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4 **Methodology**  
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6 **Participants and study sites**  
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8 Data were collected from two representative neighbouring villages with high out-migration, during 2009  
9 and 2010. The communities were selected from a pool of villages previously studied by Gibson (2002) in  
10 the Oromia region, Ethiopia, in the green midlands (altitude of 2200 to 2700m) between the town of Iteya  
11 and the city of Assala, where the socio-economics and demographic context is well known. The study  
12 communities had no electricity access, no direct road access and no working tap-water access at the time of  
13 the data collection. Community members relied mostly on a mixed economy, where cash was sporadically  
14 available. The altitude and the relatively temperate climate permits growth of a variety of cereals (wheat,  
15 teff, barley, sorghum, maize), vegetables (cabbages, carrots, potatoes, lentils, onions etc) and smaller  
16 quantities of other crop types (tobacco, oil seeds, eucalyptus) on their small farmland plot (landsize of 5ha  
17 maximum). Farmers cultivate their land with animal-drawn plows. Remittances from out-migration were  
18 rare (Gibson and Gurmu 2012) despite a relative proximity to urban centres (~10–15km). The ethnic  
19 composition of the study population includes Shoa Oromo, Arsi Oromo, and Amara. Shoa and Amara  
20 families have been intermarrying for several generations and are Christians, while Arsi Oromo are Muslims  
21 and do not usually intermarry with non-Muslims. Our sample included mostly Oromo farmers and a small  
22 number of Amara farmers (20.5% of the redistribution group and 20.6% of the inheritor group) that did not  
23 allow for more detailed analyses. Traditionally, Oromo and Amara have different inheritance systems.  
24 Contrary to most of Oromo women, Amara women had access to family land. However, governmental  
25 redistribution focused on the head of household, resulting in women being excluded from redistribution and  
26 land access. Amara women from the youngest generation are more likely to receive land from their family  
27 compared with Oromo women. However, a study on land access for an Amara population has shown a  
28 first-born son advantage for inheritance (Congdon Fors, Hounbedji, Lindskog 2017), suggesting similar  
29 patterns of parental bias for Oromo and Amara for the young generation. All families arrived between the  
30 19th century and the last Italian war (1935), and have known a system of small landlords, tenants, small  
31 landholders and landless workers. The Marxist Derg regime came to power in 1974 and started an agrarian  
32 reform in 1975. In 1975, land lordism, tenancies, inheritances were abolished, and all lands came under  
33 government control. The peasant associations (PAs), which are the lowest local administrative units,  
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4 controlled land access. PAs confiscated and redistributed periodically lands, in 1975, 1988, and 1990 to  
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6 households based on family size, land availability and land quality (Tefera et al. 2002). Today, a vast  
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8 majority of farmers in the study sites are still members of the PAs, and take part in meetings about local  
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10 development and agriculture. Informal contractual tenure arrangements were not resported as widespread in  
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12 those villages by the farmers, but might be underestimated due to their unofficial status (–up to 24% of all  
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14 farmlands in the same area might be under contract, Gavian and Ehui 1999). It is also not known to what  
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16 extent contracts are made within the family, and are, thus, not reported. Focus group discussions have  
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18 revealed numerous family strategies for land sharing among sons, including brothers sharecropping a piece  
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20 of land provided by their father, fathers passing on officially the land rights to their sons or on contrary  
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22 fathers officially maintaining their land rights while their sons farm the land, suggesting other ways to land  
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24 access than official wealth transfer from family or government. Within families, siblings reported different  
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26 roles according to birth-order rank. Elder sons were expected to take care of younger siblings, and, when  
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28 possible, to offer some large gift (i.e.: a cow) for younger brothers’ wedding. Younger brothers, on the  
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30 other hands, were expected to be obey older siblings and to serve them back through labour. Finally, some  
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32 informants specified that last-borns were expected to remain with their parents and care for them as they  
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34 age; this, in turn, might increase their access to their parents’ land. The education level is relatively low,  
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36 with few individuals finishing high-school education outside the village (11.9% and 19.4% of the  
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38 redistribution and inheritor groups, respectively). Finally, some impoverished villagers labored as daily  
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40 workers for other farmers. Non-agricultural jobs in the villages were rare and consisted mostly of  
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42 governmental jobs or religious jobs. Non-agricultural cash-generating activities (local business, crafts)  
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44 mostly served as side income to farming and were not widespread.

### 47 **Recruitment**

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50 All households in the villages were visited and heads of households (hh) were interviewed (N=590).  
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52 Multiple visits were sometimes necessary and only a few households (<10) were not recruited due to the  
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54 long-term absence of their head of household. Because the study communities are patriarchal, patrilineal  
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56 and patrilocal and present strong gender roles and enforce strong gender roles for socio-economics  
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58 activities, which likely affects people’s social networks, we focused on male head-of-household support  
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4 network. Support networks considered here include daily supports for farming and domestic activities in a  
5 broad, such a help with farm activities (ploughing, seeding, weeding, cattle care, and gifting or loan of  
6 seeds, crops, and other materials including animals), help with domestic activities (gifting or loan of food,  
7 clothes, money, water, firewood, or other materials), help during sickness (transport or care), help with  
8 house construction, and ceremonial duties. Because first-born and last-born sons might enjoy some extra-  
9 parental investment (Kidwell 1982, Hertwig, Davis and Sulloway 2002, Faurie, Russel and Lumma 2009),  
10 and because birth rank does not discriminate for the last-born category, we used three intra-sex birth-order  
11 categories (firstborn, middle born and lastborn sons) instead of birth rank. Thus, only heads of household  
12 with at least two brothers born from the same father, who survived until fifteen years old, were included in  
13 the models (N=331). Only farmers owning land rights were included, to focus on the impact of wealth  
14 transfers. Landless male farmers generally worked for other farmers, joined another household or,  
15 increasingly, moved to the city; these men likely had very different social characteristics compared with  
16 landowners.  
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### 30 31 **Procedures** 32

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34 The Ethics Committee of the University of Bristol approved all study materials and methods. Research  
35 permits were obtained from national, regional, zonal, and local Ethiopian authorities. All participants were  
36 informed about the nature of the study, data confidentiality, and of their rights to withdraw at anytime.  
37 Participants were required to either sign or fingerprint an informed consent document before participating.  
38 A pilot study was organised in a similar neighbouring community, to confirm that the questions were  
39 appropriate for the local context (e.g., non-sensitive and understood by the local community) and to  
40 identify any errors in translation or terminology. Our mixed-methods data collection approach included  
41 questionnaires, focus group discussions and semi-directed qualitative interviews. Interviews and semi-  
42 structured questionnaires following standard anthropological data collection (Fowler 1995; Krosnick and  
43 Fabrigar 1997; Bernard 2002) were undertaken. A team of seven fluent Amharic-Oromic speakers collected  
44 questionnaires from the heads of households. Questionnaires were translated from English to Oromic and  
45 then back translated. A fluent Amharic-Oromic-English speaker assisted with all interviews and focus  
46 group discussions.  
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4 **Subsamples**  
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7 The Marxist revolution, which resulted in a massive land confiscation and land redistributions, in 1975,  
8 1988 and 1990, allows for a natural experiment to study two farmer groups who received land from  
9 different sources, one from the government through the PAs and the other from their family. Because  
10 farmers did not all marry and start a family at the same age, some men from the older generations were  
11 excluded from governmental redistribution and some from the younger generation who married very early  
12 might have benefited from it. Individuals who were not part of the PA for any reason might have been  
13 excluded from governmental land access. Patterns of land transfer can be complex, however, the vast  
14 majority of men received land rights through similar pathways as their generational peers. Participants in  
15 the older group (>40 years old) mostly received their land rights from government land redistribution  
16 (redistribution farmers). 93.4% received land rights from the government. Some received it from their  
17 family (6%), and only one bought it with credit. Some men had parents who received land from  
18 governmental redistribution; thus, they might receive inheritance upon their parents' death, thus  
19 accumulating land from the government and from their family, but only a small proportion already received  
20 both government and family land (9.3%). However, most men in the older generation received land parcels  
21 equal in land and quality from the government. Respondents of the younger group (<41 years old) mostly  
22 obtained their land after the last governmental land redistribution, and where thus, dependent upon their  
23 parents (=inheritor farmers) for land access. 89.4% received land from their families. 10% received land  
24 from the government only. Only one farmer bought it. A small proportion received land from both their  
25 family and the government (10%).  
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46 **Data**  
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48 Socio-economic, demographic and support network data about households and household heads were  
49 collected with questionnaires during interviews. Support network data were generated from both questions:  
50 1) Whom do you help on a daily basis for agricultural and domestic support? 2) Who are your daily helpers  
51 for agricultural and domestic support? For both questions, respondents gave the person's full name,  
52 relationship, place of residence, and type of support provided. When the same person was cited for both  
53 responses, we labeled the contact as a (direct) reciprocator, when the person was cited for only one answer;  
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4 we labeled the contact a non-direct reciprocator. Herein, we define reciprocity as here current direct  
5 reciprocity at the time of data collection; and we define non-direct reciprocity as all other bi-directional  
6 interactions (e.g., contingent reciprocity on longer timescale) or unidirectional (altruism or indirect  
7 reciprocity, which are difficult to discriminate from each others). We preferred the terminology “non-  
8 direct reciprocity” over “altruism”, because it includes indirect reciprocity (through one, several or many  
9 peers), and also delayed reciprocity. Degrees of reciprocity were too complex to be measured, for example,  
10 help received and given might or might not be of equal value, intrinsically or relatively to the mutual  
11 interactants (considering each person’s age, wealth or social status, physical condition, energy needs and  
12 expenditure etc.), nor of perceived equal value. We extracted the network configuration (presence or  
13 absence of support -received and/or given) and support network size (number of supporters or number of  
14 persons helped) from each participant’s responses.

15  
16 Respondent age, farmland size (ha), village (1 or 2), parents being alive or deceased and number of  
17 brothers or sibling who survived to 15 years old were included in the models when possible.

18  
19 Because there are redundancies across religious affiliation and ethnicity (Amara and Shoa Oromo are  
20 Christians, while Arsi Oromo are Muslims), religion (Christians/Muslims) was preferred as a main-effect  
21 variable over ethnicity (Shoa/Arsi/Amara) because it better represents the between-group differences in  
22 among the participants. We also included education level (finished high school education/not) in our  
23 models.

24  
25 Farmers from village 1 have significantly smaller plots of land ( $1.24 \pm 1.06$ ) compared to village 2  
26 ( $1.70 \pm 1.20$ ; Mann Withney U Test:  $U=9848.00$ ,  $z=-4.091$ ,  $p=0.0001$ ), they also reported  
27 (mean $\pm$ sd= $3.10 \pm 1.47$ ) significantly smaller network sizes than village 2 farmers ( $3.69 \pm 1.18$ , Mann  
28 Whitney U test,  $U=10322.00$ ,  $z=-3.614$ ,  $p=0.000$ ), which is why we discriminated between villages 1 and 2  
29 in the models.

30  
31 Some studies have suggested that of network size and structure remain relatively consistent across the  
32 lifespan, despite individual variations (e.g. Dunbar 2008). Those variations might affect network  
33 composition and network size, which is why we also explored age (Hill and Dunbar 2003) and wealth  
34 effects. For example, young parents might receive more support from kin for domestic work and might  
35 require more support from experienced and older farmers. Young people might be capable of providing  
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4 more support due to their youth and physical strength, while people might begin to receive support as they  
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6 age.

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8 Connections between material capital and social capital have been shown many times (Lewis 2010). We  
9  
10 choose farmland size as a proximate for material capital, because it is a key resource in our study for  
11  
12 survival and reproductive outcomes (Gibson and Gurm 2011) was chosen. Previous pilot studies showed  
13  
14 that wealth oriented questions were sensitive. Indeed, we found that farmers were uncomfortable answering  
15  
16 questions about wealth, but accepted questions about the size of their land, which is public knowledge  
17  
18 anyway. Questions about livestock appeared to be fairly sensitive.

19  
20 Thus we narrowed our questions about wealth to farmland size. Because most of the farming is agricultural  
21  
22 a focus on farmland size was adequate, especially considering that both villages had similar ecologies and  
23  
24 agro-systems. Furthermore, because farmers use oxen for animal traction to work the land, the number of  
25  
26 oxen owned is usually proportionated to the farmland size.

27  
28 Variation in farmland size is reduced (range: 0.25-5ha only), probably because the last Marxist  
29  
30 redistribution was fairly recent (1992), and it may be that not enough time has passed for inequalities to  
31  
32 grow. However, because social capital includes a collective dimension through interactions between  
33  
34 community members, it was relevant to consider respondent relative wealth in their village. We tested for  
35  
36 an interaction effect between land size and village, but we did not include them in final models when they  
37  
38 yielded non-significant results.

#### 39 40 **Database and data analyses**

41  
42 Socio-economic, demographic, and social-network data were input in into a Microsoft Access (Redmond,  
43  
44 WA, USA) database. IBM SPSS Statistics for Macintosh, version 22.0. software was used for all analyses.  
45  
46 (IBM, Armonk, NY, USA). We created one large data frame that included socio-economic, demographic,  
47  
48 and network size and composition data for each respondent. Descriptive statistics are presented in the  
49  
50 appendix.

51  
52 Generalized linear models with Poisson regressions were fit to compare birth-order categories effects on  
53  
54 full network size, kin network size, non-parental kin network size, number of non-parental kin reciprocators  
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56 and number of non-kin reciprocators. Independent variables were: age, land size, village, religion,  
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education, sibling size or male sibling size, land origin, and generational group. Estimated marginal means are presented in the figures.

We fit logistic regressions with independent variables to identify effects of birth-order categories associated with parental interactions among farmers' support networks. We only performed analyses of parent interactions for the inheritor group, because a large proportion of the redistribution group (respondent > 40 years old) have elderly or deceased parents or deceased parents (87% of the inheritor group had at least one parent being alive, for 36% of the redistribution group). Logistic regressions were performed for three types of interactions: 1) parents cited as interactants (helpers or receivers) 2) parents are named as helpers 3) parents are named as reciprocators. Independent variables we included in the models were: age, education, religion, land size and respondent village, intra-sex birth-order categories, and survival of at least one parent/none.

Wilcoxon signed ranks tests were performed for respondents of both groups to compare the number of kin to the number of non-kin, the number of close kin (parents, children and sibling) to the number of distant kin (other kin).

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4 **Results**  
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7 We estimated that mean ( $\pm$  sd) network sizes for domestic and agricultural interactions were  $3.48 \pm 1.24$  for  
8 the inheritor group and  $3.18 \pm 1.51$  for the redistribution group. Two major trends emerged from our  
9 analyses: 1) Support networks varied according to competition among brothers and 2) reciprocity and kin-  
10 selection shaped farmers' daily support networks.  
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16 Prediction 1: Support networks varied according to birth-order biases  
17

18 We fit GLMs with Poisson regression to explore the impact of intra-sex birth order on network size and kin  
19 network size, while controlling for age, number of male siblings, land size, and village (Table 1). In model  
20 1, only village had an effect on total network size (kin and non-kin), where village 1 respondents reported  
21 smaller networks than village 2 respondents (village 1/2 ratio: expB (95% CI)=0.8 (0.7–1.0), P=0.010).  
22 When focusing on the number of kin cited (model 2), an intra-sex birth-order effect was present among  
23 first-born sons (expB (95% CI)=1.5 (1.1–2.0), P=0.005) and middle-born sons (expB (95% CI)=1.5 (1.2–  
24 2.0), P=0.002) who both reporting more kin than last-born sons. Because the law states that both males and  
25 females can inherit, a similar model that includes birth order for all children instead of just brothers was  
26 tested (Model 4, Table 1), but no significant birth-order effect was observed, suggesting that indeed intra-  
27 sex birth order is a better measure of competition than overall sibling birth order.  
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38 Age did not have a significant effect on network size in the above models. However, when we  
39 discriminated between the inheritor and redistribution generations and when we controlled for an  
40 interaction effect between generation and birth order, significant differences in kin network sizes were  
41 observable according to birth-order categories (Table 1, Model 3, Figure 1), with first-born sons of the  
42 inheritor group and middle-born sons of the redistribution group having the most kin in their networks.  
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52 **Fig. 1** Number of kin, listed in support networks, presented as marginal means +SE (N=331) for each intra-  
53 sex birth-order categories (first, middle and last-born sons) and generations (inheritor and redistribution  
54 groups). Covariates appearing in the model are fixed at the following values: male sibling size=5, land  
55 size=1.43ha. Controlling for village and generations (inheritor vs. redistribution group). FB=first-born,  
56 MB=middle-born, LB=last-born  
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7 Across generation, kin accounted for over half of the people in respondents' networks (57.1% and 51.2%  
8 for the inheritor and redistribution groups, respectively, Table 2). Interactions with parents accounted for  
9 17.1% and 6.0% of respondents' total interactions for the inheritor and redistribution groups, respectively.  
10  
11 Interactions with non-parental kin (40.0% and 45.2% overall for the inheritor and redistribution groups,  
12  
13 respectively) were distributed as follows: 22.5% and 17.7% were with brothers, 0.6% and 15.8% were with  
14  
15 children, and 4.5% and 2.3% were with sisters. The small proportion of daily interactions with sisters is due  
16  
17 to the local custom of women marrying outside their community.  
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21 To understand how direct reciprocity and non-direct reciprocity contribute to individual support networks,  
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23 different types of interactions were explored for each of the main interactant categories, which included  
24  
25 parents and non-parental kin.  
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### 28 **1.1 Interactions with parents**

29

30 Among the inheritor farmers (n=180), 55% named at least one parent as an interactant, and half of those  
31  
32 reported a reciprocating relationship (n=49). Reciprocal relationships with parents were reported by 67.4%,  
33  
34 47.6%, and 61.3% of first-born, middle-born, and last-born sons, respectively. Parents as helpers were  
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36 reported by 43.5%, 27.2%, and 29.0% of first-borns, middle-borns, and last-borns, and 63.0%, 45.6% and  
37  
38 58.1% reported helping a parent. Middle-born sons reported parent interactants significantly less often than  
39  
40 other sons (likelihood-ratio=5.416, df=1, P=0.020), because first-born sons reported a parent helper  
41  
42 (likelihood-ratio=3.855, df=1, P=0.050) and a reciprocating parent ((likelihood-ratio=4.227, df=1, P=0.040)  
43  
44 most often, while middle-born sons reported helping their parents less than other sons (likelihood-  
45  
46 ratio=4.216, df=1, P=0.040).  
47

48 As expected, when controlling for birth order, village, religion, and having a living parent among farmers  
49  
50 in the same generation, younger farmers were more likely to cite parents in their networks than older  
51  
52 farmers (age: OR (95% CI)=0.9 (0.8–1.0), P=0.025; Model 1, Table 3).  
53

54 Consistent with our expectations, we also found a first-born positive bias in citing parents in networks.  
55  
56 However, when comparing birth-order categories, middle-born sons were significantly less likely to cite a  
57  
58 parent in their network compared with first-born sons (OR (95% CI)=0.4 (0.2–1.0), P=0.045), but we found  
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4 no significant difference between first- and last-born sons (OR (95% CI)=0.8 (0.3–2.3), P=0.726; Model 1,  
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6 Table 3). These results suggest that first- and last-born sons are more likely to have parent interactants than  
7  
8 middle-born sons.  
9

10 Parents invest in their children in various ways, providing, for example, education and material wealth.  
11  
12 When education and land-size transfers were included in the model, evidence for birth-order biases were  
13  
14 insignificant (OR (95% CI)=0.5 (0.2–1.1), P=0.075 and OR (95% CI)=0.9 (0.3–2.6), P=0.841; Model 2),  
15  
16 suggesting that daily interactions with parents might not be biased in favour of birth order when other types  
17  
18 of investment are controlled for. Farmers who completed high school were significantly more likely to  
19  
20 report their parents as interactants compared with other farmers, (OR (95% CI)=4.0 (1.5–10.7), P=0.006;  
21  
22 Model 2). Finally, we found no birth-order biases among sons reporting a parent as a reciprocator (OR  
23  
24 (95% CI)=0.5 (0.2–1.1), P=0.101 and OR (95% CI)=0.5 (0.2–1.5), P=0.241; Model 3) or among sons  
25  
26 reporting a parent as a direct supporter (OR (95% CI)=0.5 (0.2–1.1), P=0.095 and OR (95% CI)=0.5 (0.2–  
27  
28 1.4), P=0.172; Model 4).  
29

### 30 **1.2 Non-parental kin and non-kin support**

31  
32 Non-parental interactions comprised an important component of social-support networks in our dataset:  
33  
34 42.28% of interactants were non-parental kin, including 40.03% among the inheritor group and 45.21%  
35  
36 among the redistribution group.  
37

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39 GLMs with Poisson regression revealed a significant difference in the total number of non-parental kin  
40  
41 interactants cited by inheritor farmers across the three different birth-order categories, controlling for age,  
42  
43 number of male siblings, land size, village, education, and religion. We observed a decrease in the number  
44  
45 of non-parental kin cited with successive birth-order categories (Fig. 2). Middle-born and last-born sons  
46  
47 reported fewer non-parental kin in their networks compared with first-born sons (expB (95% CI)=0.7 (0.6–  
48  
49 1.0), P=0.062, expB (95% CI)=0.5 (0.3–0.8), P=0.003, reciprocally). None of the control variables had a  
50  
51 significant effect on model fit (Table 4). Those birth-order biases appeared to result from non-direct-  
52  
53 reciprocal interactions. There was not a significant difference in reporting reciprocators among sons of  
54  
55 different birth-order categories (reciprocally expB (95% CI)=0.9 (0.6–11.4), P=0.817, (expB (95% CI)=0.7  
56  
57 (0.4–1.3), P=0.257). Among the control variables, only village had an effect, with respondents from village  
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59 1 reporting fewer reciprocators than those in village 2 (expB (95% CI)=0.6 (0.4–0.9), P=0.018).  
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7 **Fig.2** Effect of intra-sex birth-order categories on the number of non-parental kin cited in daily support  
8 networks for the two groups.  
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11 **Fig.2a** Number of non-parental kin cited presented as marginal means (+SE); n=180, first-born sons (FB)  
12 n=46; middle-born sons (MB) n=103, last-born sons (LB) n=31. Covariates appearing in the model are  
13 fixed at the following values: number of male siblings=5.07, land size=0.64 ha, age of respondent=31.48  
14 years. We controlled for religion, education level, village, and land origin  
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20 **Fig.2b** Number of non-parental kin cited are presented as marginal means (+SE); n=151, first-born sons  
21 (FB) n=48; middle-born sons (MB) n=79; last-born sons (LB) n=24. Covariates appearing in the mode are  
22 fixed at the following values: number of male siblings=4.91, land size=2.38 ha, respondent age =57.75  
23 years. We controlled for religion, education level, land origin, and village  
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31 Results for the redistribution group followed a different pattern, where we found significant differences  
32 across the three birth-order categories. First- and last-born sons reported fewer non-parental kin in their  
33 networks compared with middle-born sons (expB (95% CI)=0.6 (0.5–0.9), P=0.010 and expB (95%  
34 CI)=0.5 (0.3–0.8), P=0.004). Only religion had a significant effect as a control variable, with Christians  
35 having larger networks than Muslims (expB (95% CI)=1.8 (1.0–3.1), P=0.045). Due to our small sample  
36 size, pairwise comparisons of the estimated marginal means were run for middle-born sons compared with  
37 other birth-order sons for both religions. Similar patterns were noticeable for Christians and Muslims, with  
38 middle-born sons citing more non-parental kin compared with other sons (Christians: mean difference  
39 (middle-born vs. other sons)±SE=0.61±0.19, P=0.001; Muslims: mean difference (middle-born vs. other  
40 sons)±SE=0.35±0.16, P=0.016). Religion did not impact patterns of birth-order biases. Birth-order biases in  
41 non-parental kin network size were dependent of non-reciprocal interactions as we found no significant  
42 differences in the number of reciprocators according to birth order (expB (95% CI)=1.0 (0.6–1.6), P=0.924  
43 and expB (95% CI)=0.9 (0.5–1.8), P=0.814). When controlling for all other variables, village, high-school  
44 education, land size, and land origin (redistribution vs. inheritance) had a significant effect on the number  
45 of reciprocators. Farmers from village 1 reported fewer reciprocators (expB (95% CI)=0.5 (0.3–0.8),  
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4 P=0.009), as did farmers without a high-school education (expB (95% CI)=0.3 (0.2–0.7), P=0.002).  
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6 Farmers with larger land holdings reported more reciprocators (expB (95% CI)=1.4 (1.0–1.8), P=0.027),  
7  
8 and, finally, farmers who did not receive land from family reported having more reciprocators (expB (95%  
9  
10 CI)=2.0 (1.0–4.2), P=0.050).

#### 11 12 Prediction 2: Reciprocity and kin-selection shape farmers' daily support networks

13  
14 The inheritor group cited more kin than non-kin ( $z=-2.455$ ,  $P=0.014$ , Wilcoxon signed-rank test), while the  
15  
16 redistribution group cited as many kin as non-kin ( $z=-0.236$ ,  $P=0.814$ ). A substantial component of kin  
17  
18 interactions was based on daily direct reciprocity: 49.7% of kin interactions of the inheritor farmers and  
19  
20 37.4% of kin interactions of the redistribution farmers were direct-reciprocal interactions, which suggests  
21  
22 the importance of direct payoff even with kin.

23  
24 Respondents reported significantly more close-kin reciprocators than distant-kin reciprocators ( $N=331$ ,  $z=-$   
25  
26  $8.849$ ,  $P<0.0001$ , Wilcoxon signed-rank tests), suggesting that reciprocity with close kin might be favoured  
27  
28 because of the compound profits of direct-reciprocity payoffs and indirect-fitness payoffs from kin  
29  
30 selection. Both farmer groups reported significantly more reciprocal interactions with close kin than distant  
31  
32 kin (inheritor farmers:  $n=180$ ,  $z=-6.313$ ,  $P<0.0001$ ; redistribution farmers:  $n=151$ ,  $z=-4.857$ ,  $P<0.0001$ ,  
33  
34 Wilcoxon signed-rank tests).

35  
36 Farmers reported significantly more non-reciprocal interactions with kin than with non-kin (all  
37  
38 respondents:  $N=331$ ,  $z=-5.545$ ,  $P<0.0001$ ; inheritor group:  $n=180$ ,  $z=-4.402$ ,  $P<0.0001$ ; redistribution  
39  
40 group:  $n=151$ ,  $z=-3.444$ ,  $P=0.001$ , Wilcoxon signed-rank tests). They also reported significantly more non-  
41  
42 reciprocal interactions with close kin than with distant kin (all respondents:  $N=331$ ,  $z=-8.296$ ,  $P<0.0001$ ;  
43  
44 inheritor group:  $n=180$ ,  $z=-5.727$ ,  $P<0.0001$ ; redistribution group:  $n=151$ ,  $z=-6.025$ ,  $P<0.0001$ , Wilcoxon  
45  
46 signed-rank tests). This trend held when considering only non-reciprocal helpers: farmers reported  
47  
48 significantly more non-reciprocal kin helpers than non-reciprocal non-kin helpers (all respondents:  $N=331$ ,  
49  
50  $z=-2.545$ ,  $P=0.011$ ) and significantly more close-kin non-reciprocal helpers than distant-kin non-reciprocal  
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52 helpers (all respondents:  $N=331$ ,  $z=-4.762$ ,  $P=0.0001$ ).  
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4 **Discussion**  
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6 The findings from this natural experiment allow us to identify patterns of intra-household inequalities in  
7 terms of support networks for two wealth transmission modalities. Where material wealth is inherited,  
8 support network inequalities follow patterns of material inequalities, like the ones observed by Gibson and  
9 Gurmu (2011), suggesting that social capital in support networks reinforces material inequalities between  
10 brothers in the context of limited resources. When wealth is not inherited and all sons had equal access to  
11 land, other patterns of support network biases appeared, suggesting that social capital might at least partly  
12 offset the disadvantage of sons receiving the least cumulative parental investment, which is consistent with  
13 findings from Salmon (2003), Rhode et al. (2003), Salmon and Daly (1998). Overall, our findings suggest  
14 that heritable wealth and land transfers, by influencing material and social capital, might have an important  
15 role in the emergence and persistence of inequality in this agricultural population, similar to findings by  
16 Smith et al. (2010). Our findings also imply that direct reciprocity appears to explain an important part of  
17 kin cooperation, providing additional support for a more nuanced explanation of kin cooperation compared  
18 with sole kin selection, as found in a number of different contexts (Jaeggi and Gurven 2013). Here,  
19 support-network sizes were consistent with predictions from the literature, particularly Dunbar’s work on  
20 biological constraints on human social networks, which predicts that “natural” support-network sizes range  
21 from 3–5 people (Dunbar & Spoor 1995, Zhou et al. 2005, Hamilton et al. 2007).  
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39 Prediction 1: Birth-order biases in support-network size and composition  
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41 We found strong evidence of kin-selection, coinciding with multigeniture with a first-born son advantage,  
42 in the inheritor group. First-born farmers were more likely to name parents as daily support partners,  
43 particularly as reciprocators. Thus, first-borns preferentially received parental investment, but also, by  
44 reciprocating, reduced their parents’ potential kin-selection costs. However, when controlling for other  
45 variables, this effect was weaker and, at best, an insignificant tendency. Non-parental kin support size was  
46 biased toward first-born sons, an effect that was not driven by reciprocity. This pattern reveals that first-  
47 born farmers are advantaged in terms of both material (Gibson and Gurmu 2011) and social capital, which  
48 decreases their household vulnerability relative to other farmers. We also found that middle-born and last-  
49 born sons diversified their networks by reciprocating with more non-kin compared with first-born sons.  
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4 networks, possibly because they diversified their networks to include more non-parental kin (Salmon and  
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6 Daly 1998, Salmon 2003, Rhode et al. 2003). Middle-born farmers reported more non-parental kin in their  
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8 networks than did other farmers, and these interactions were mostly characterized by non-direct reciprocal  
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10 interactions, suggesting other non-exclusive mechanisms than direct reciprocity, such as kin selection,  
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12 delayed reciprocity, or indirect reciprocity. For both groups, last-born sons were among the most  
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14 disadvantaged in terms of their kin-support networks, as they reported fewer kin than other inheritor  
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16 farmers. According to Gibson and Gurmu (2011), “the number of elder brothers reduces a man’s  
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18 agricultural productivity, marriage, and reproductive success, as resources diminish and competition  
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20 increases with each additional sibling.” Thus, a last-born disadvantage in material resources and fitness was  
21  
22 sufficiently impactful to generate a negative bias in daily kin support and to drive last-borns to diversify  
23  
24 their network to non-kin through reciprocity. A negative kin bias might be even more dramatic for last-born  
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26 sons who had no land access, possibly forcing them to leave their community for low-skilled jobs in urban  
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28 centres.  
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31 Last-born farmers from the redistribution group were also disadvantaged. Alongside first-born sons, they  
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33 reported less non-parental kin support compared with middle-born sons, but they tended to report more  
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35 diversification via reciprocity with non-kin compared with their brothers. These results suggest a possible  
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37 continuity of first-born son preference during the redistribution period, which might not have been entirely  
38  
39 offset by the governmental land redistribution. Despite sweeping redistribution policies of the revolution-  
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41 era government, evidence suggests that not all intra-household and inter-household resource inequalities  
42  
43 were dismantled. Our focus group discussions and qualitative-interview informants told us that the socio-  
44  
45 economic statuses of families in past generations were still important for arranging marriages. Brothers  
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47 might not have had to compete for a critical livelihood resource because they all received equal plots from  
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49 the government, but there are other pathways through which sibling competition could arise. On the one  
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51 hand, a first-born son advantage could persist into later years, which could lead to first-born sons being  
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53 more family oriented and less non-kin oriented than other sons. On another hand, last-born sons might  
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55 work harder and take more risks to build non-kin relationships through direct reciprocity, which is  
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57 consistent with farmer comments during focus groups. Last-born sons were said to be “more difficult to  
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59 discipline” in younger ages, but also more “free, more rebellious, more obstinate, more friend-oriented, and  
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4 also more risky and adventurous,” compared with their older brothers. Sulloway (1996) claimed that  
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6 parental investment and sibling competition create a niche effect during childhood that influences  
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8 construction of personality and sociability constructs that persist into adulthood. Other studies have  
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10 investigated the influence of family size and composition on personality and social attitudes at young ages  
11  
12 (Salmon and Daly, 1998, Salmon 2003); some of these studies found that biases persist into adulthood  
13  
14 when offspring are less dependent on parental investment (Salmon 1998), but others found that parental-  
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16 investment biases are less influential (Pollet and Nettle 2009) or absent (Rhode et al. 2003, Pollet and  
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18 Nettle 2007, 2009) in adulthood, possibly because of adjustments in support-network configuration over a  
19  
20 lifetime. We observed significant biases among adult farmers in our study sample, suggesting the  
21  
22 importance of material and social resources in shaping support.  
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24 Respondent age tended to affect network size, probably only because parents were more often cited as  
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26 interactants by the younger-generation farmers. Age was not associated with non-parental kin and non-kin  
27  
28 interactions, even when we evaluated the two generations separately. Within the inheritor group, younger  
29  
30 farmers were expected to interact more with kin than older farmers, because they had higher reproductive  
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32 value, probably had less agricultural experience, had less labour power within their households because  
33  
34 their children were still very young, and had younger parents with more ability to help. On the one hand,  
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36 older farmers in the redistribution group could be expected to interact with more people generally,  
37  
38 including kin, because of their elder status; on the other hand, they could be expected to interact with fewer  
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40 people, because they have less ability to reciprocate support. Our results suggest that compositional changes  
41  
42 in agricultural and domestic interactions, rather than network size changes, might occur during farmers’  
43  
44 lifetimes; such compositional changes include interactant identities, interaction type, and direction of  
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46 interaction.  
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49 We also found that religion, education, and village had a significant effect on networks, revealing the  
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51 importance of individual and community context. Muslims were a minority in the study villages, so they  
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53 might have had fewer kin in their village and might have had a preference for Muslim interactants; hence,  
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55 Muslim inheritors would have fewer non-parental kin and redistribution farmers would have fewer non-kin  
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57 reciprocators than Christians. High-school education appears to be an attractive characteristic for  
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59 reciprocity among non-parental kin, in the context of equal land access, because high-school educated  
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4 farmers from the redistribution group reported more non-parental kin reciprocators. Finally, we observed a  
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6 significant village effect, with farmers from village 1 reporting significantly smaller networks compared to  
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8 farmers in village 2.  
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11 In this population, wealth, as measured by land size, did not seem to influence farmers' networks, apart  
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13 from the number of non-parental kin reciprocators in the redistribution group, suggesting that origin of land  
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15 access (inheritor vs. redistribution) was more impactful than land size on kin investment in daily support  
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17 networks. Land size among our sample was fairly homogenous and the variance was small; furthermore,  
18  
19 only landowners were included and they were all from large families with at least three sons. Because of  
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21 unmeasured informal arrangements for land access (Gavian and Ehui 1999), official land size might be an  
22  
23 underestimated proxy for the actual land size used for production. Therefore, it might be fruitful to explore  
24  
25 other types of wealth. Cues about the connection between support networks and material resources,  
26  
27 especially in difficult times, have been identified. For example, Caudell, Rotolo and Grima (2015), showed  
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29 that, among the Sidamo people of southern Ethiopia, charismatic individuals in informal lending networks  
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31 were wealthier than other farmers in terms of cattle herd size. Other work, identified non-linear wealth  
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33 dynamics on the formation of informal insurance networks, with the poorest being excluded from those  
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35 networks (Santos and Barrett 2006).  
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37 However, in our pilot work in the study site, low variation was observed in herd sizes. Farmers used a pair  
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39 of oxen to work their land, and might have two pairs if they have larger land holdings. Thus, more complex  
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41 indexes might be necessary to evaluate wealth. It is also possible that resources might have a smaller  
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43 impact on daily interactions compared with their impact on insurance networks, where resources increase  
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45 resilience in difficult times.  
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#### 47 Prediction 2: Reciprocity and kin-selection shape farmers' daily support networks

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49 Our results showed that kin make up an important proportion of support networks, which is consistent with  
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51 kin-selection theory (Hamilton 1964). In small-scale societies, close kin are overrepresented compared with  
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53 distant kin and non-kin (Gurven et al. 2000, Patton 2005). Kin over-representation is also visible in  
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55 Western societies (Dunbar and Spoons 1995). However, reciprocity (including reciprocal altruism as per,  
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57 Trivers 1971) plays an important role in shaping support ties among kin (Patton 2005, Gurven et al. 2000).  
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59 For instance, Hames (1987) suggested that, in Venezuela, "the Ye'kwana system of garden labour  
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4 exchange is a form of reciprocity biased by kinship.” Additionally, food transfers on an Ache reservation in  
5 northeastern Paraguay “accords better with reciprocal altruism theory than with kin selection theory”  
6 (Allen-Arrave, Gurven and Hill 2008). Finally a meta-analysis of 23 studies from 32 populations of humans  
7 and primates highlighted the importance of reciprocity on shaping cooperation, and demonstrated that the  
8 relative effect of reciprocity for sharing was similar to those of kinship and tolerated scrounging (Jaeggi  
9 and Gurven 2013).

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17 Non-reciprocal interactions should be more common among kin than non-kin, and among close kin than  
18 distant kin, because of indirect fitness payoffs. Reciprocity theory (Trivers 1971) potentially explains most  
19 interactions with non-kin, as well as many kin interactions, especially distant kin with whom indirect-  
20 fitness profits from helping behaviour are relatively lower (Hames 1987, Gurven et al. 2000, Allen-Arrave,  
21 Gurven and Hill 2008). We expected most non-kin interactions to be reciprocal, but expected more  
22 variation in reciprocity among kin interactions. In fact, support networks constituted multi-directional  
23 interactions: respondents stimulated and modulated their support by lowering the giver’s costs through  
24 some amount of daily direct and indirect reciprocity. Interestingly, kin were frequently included in  
25 reciprocal relationships, even though the frequency of non-reciprocal interactions among kin increased with  
26 genetic relatedness. Delayed (contingent) reciprocity, which is difficult to evaluate and identify, might have  
27 been mistaken in our dataset for non-reciprocal interactions, and so there may be even more variations and  
28 higher quantities of reciprocal relationships among these farmer communities. According to these results,  
29 even when considering classification of direct reciprocity/non-direct reciprocity and even when the last  
30 category includes contingent (delayed) and indirect reciprocity (through another person), patterns for non-  
31 reciprocal interactions followed predictions of kin selection while reciprocity, alongside kin selection,  
32 appeared to be an important driver of daily reciprocal kin interactions. In other words, kin selection does  
33 not appear to be the sole explanation for support received from kin.  
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## 51 **Conclusion**

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55 Two major implications can be drawn from our findings in this natural-experiment context. First, we were  
56 able to understand how heritable wealth shapes daily support networks in a contemporary agricultural  
57 community and how it contributes to intra-household inequality. Our findings are consistent with Smith et  
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al (2010) and Boone (1992) who concluded that the control and transmission of scarce inelastic wealth, such as farmland, was an important factor in the emergence of inequality.

Second, in this small-scale land-based community, both kin selection and reciprocity shaped adult farmers' daily support networks, suggesting that reciprocity is important for cooperation among kin, as also shown by Jaeggi and Gurven (2013) in a number of contexts.

Our findings shed light on the behaviour and evolution of human social interactions by showing that people and their kin adjust their daily support behaviour in a complex manner that is consistent with fitness predictions. Increased socio-demographic and economic changes are expected in Ethiopia. Contraception has recently become more widespread (Alvergne et al. 2012), leading to a smaller average family size, which might change future intra-household resource distribution by reducing resource dilution. However, because of on-going population growth, land erosion, and limited arable land (Tefera et al. 2002)—all of which will only grow more serious with climate change and geo-political instability—resource scarcity and livelihood insecurity are likely to increase and further aggravate competition and inequalities, within and between households. Some individuals will likely have greater resilience in times of shock because they can rely on their networks (Caudell, Rotolo and Grima 2015), while the poorest and most vulnerable might not have the social resources to respond (Santos and Barrett 2006) and may be pushed to urban areas.

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Biosketch

**Does kin-selection theory help to explain support networks among farmers in South-Central Ethiopia?**

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Lucie Clech obtained a PhD in Evolutionary Anthropology from the University of Bristol, focusing on human behavioural ecology of migration in Ethiopia, before undertaking postdoctoral research at Stanford University. Her research covers topics about poverty and family dynamics and includes migration, social interactions, education and health in resource-limited communities. Her interdisciplinary background in ecology and social sciences led her to focus especially on dynamics of livelihood strategies in response to modifications in their socio-economic and demographic environment.

Ashley Hazel holds a PhD in Natural Resource Ecology from the University of Michigan, and she is currently a Research Scientist at Stanford University in the Department of Earth System Science. Her research interests include human disease ecology, social network theory, and subsistence migration.

Mhairi Gibson is an Associate Professor in Anthropology at the University of Bristol. As an applied evolutionary anthropologist her work applies ideas from human behavioural ecology to emerging population health issues in low-income settings. Her fieldwork-based research has explored the causes and consequences of human population and health change in rural Ethiopia, and the social dynamics of normative practices which are harmful to women. Mhairi Gibson was lead editor (with David Lawson) of 'Applied evolutionary anthropology: Darwinian approaches to contemporary world issues', published by Springer Science & Business Media (2014).

## Tables

### **Does kin-selection theory help to explain support networks among farmers in South-Central Ethiopia?**

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Table 1. GLMs with Poisson regression for network size (model 1) and kin network size (model 2,3,4). N=331.

Models:	Model 1		Model 2		Model 3		Model 4	
	ExpB(95%CI)	P	ExpB(95%CI)	P	ExpB(95%CI)	P	ExpB(95%CI)	P
Intercept	4.4(3.4-5.7)	0.000**	1.8(1.2-2.6)	0.004**	1.7(1.2-2.5)	0.003**	2.2(1.5-3.4)	0.000**
Age of respondent (years)	1.0(1.0-1.0)	0.067	1.0(1.0-1.0)	0.282			1.0(1.0-1.0)	0.365
BO: First-born children(/last)							1.2(0.8-1.6)	0.361
BO: Middle-born children(/last)							1.2(0.9-1.6)	0.225
Sibling size (males and females)							1.0(1.0-1.0)	0.273
BO: First-born sons (/last)	1.0(0.8-1.2)	0.715	1.5(1.1-2.0)	0.005**	1.5(1.1-2.1)	0.015*		
BO: Middle-born sons (/last)	1.08(0.9-1.3)	0.362	1.5(1.2-2.0)	0.002**	1.2(0.8-1.6)	0.344		
Number of male siblings	1.0(1.0-1.0)	0.708	1.0(0.9-1.0)	0.943	1.0(1.0-1.0)	0.961		
Village 1 (/2)	0.8(0.7-1.0)	0.010**	0.9(0.8-1.1)	0.200	0.9(0.8-1.1)	0.348	0.9(0.7-1.0)	0.160
Land size (ha)	1.0(0.9-1.1)	0.532	0.9(0.8-1.1)	0.475	1.0(0.8-1.1)	0.532	0.9(0.8-1.1)	0.394
Generations (redist/inheritor)					0.6(0.3-1.0)	0.048*		
Firstborn sons*generations (redist/inheritor)					1.0(0.5-1.8)	0.981		
Middleborn sons*generations (redist/inheritor)					2.0(1.1-3.5)	0.014		

Notes: There was no interaction effect between land size x village, so they were not included in the models. Model 1=number of interactants cited in networks, model 2, 3, and 4=number of kin interactants cited in networks. Model 3 is a variation of model 2 and includes generational group and an interaction effect BO\*generational group. Model 4 includes birth-order categories instead of intra-sex birth-order categories. \* p=0.05 \*\*p=0.01

Table 2: Distribution by interactant relatedness

	Total number of interactants	Interactants (% for all interactants)								
		Non-kin	All kin	Parents	Non-parental kin	Close kin	Brothers	Sisters	Children	Distant kin
All	1107	45.44	54.56	12.28	42.28	43.45	20.41	3.52	7.23	11.11
Inheritor group	627	42.90	57.10	17.06	40.03	44.66	22.49	4.46	0.64	12.44
Redistribution group	480	48.75	51.25	6.04	45.21	41.87	17.71	2.29	15.83	9.37

Note: Distant kin include kin and in-laws who are not parents, siblings, or children.

Table 3: Logistic regressions for reporting at least one parent in their network.

Models:	Model 1		Model 2		Model 3		Model 4		
	OR(95%CI)	P	OR(95%CI)	P	OR(95%CI)	P	OR(95%CI)	P	
Age of respondent	180	0.9(0.8-1.0)	0.025 *	0.9(0.8-1.0)	0.011 *	0.9(0.8-1.0)	0.010 **	0.9(0.8-0.9)	0.002 **
Intrasex birth-order categories			0.095		0.141		0.233		0.200
Middle-born(/first)	103/46	0.4(0.2-1.0)	0.045 *	0.5(0.2-1.1)	0.075	0.5(0.2-1.1)	0.101	0.5(0.2-1.1)	0.095
Last-born(/first)	31/46	0.8(0.3-2.3)	0.726	0.9(0.3-2.6)	0.841	0.5(0.2-1.5)	0.241	0.5(0.2-1.4)	0.172
Number of male siblings	180	1.0(0.8-1.2)	0.847	1.0(0.8-1.2)	0.940	0.9(0.8-1.2)	0.638	0.9(0.8-1.1)	0.522
High school educated (/not educated)				4.0(1.5-10.7)	0.006 **				
Land size (ha)	180			1.0(0.5-12.0)	0.905				
Village 1(/2)	105/75	0.4(0.2-0.9)	0.030 *	0.4(0.2-0.8)	0.014 *	0.4(0.2-0.9)	0.026 *	0.6(0.3-1.2)	0.129
Christians (/Muslims)	143/37	0.5(0.2-1.2)	0.119	0.4(0.2-1.1)	0.092	0.8(0.3-2.5)	0.846	0.6(0.2-1.4)	0.242
Land provided by the family (/not)				1.3(0.4-4.1)	0.635				
Constant		16.904	0.072	25.0	0.089	14.058	0.128	32.7	0.039 *

Notes: Logistic regressions for models 1 and 2: citing at least one parent in their network, model 3: reciprocating with at least one parent and model 4: reporting support from at least one parent. Model 2 is a variation of model 1 and includes different types of parental investment (land size, land transferred and education). Controlling for having at least one alive parent. \* p=0.05 \*\*p=0.01

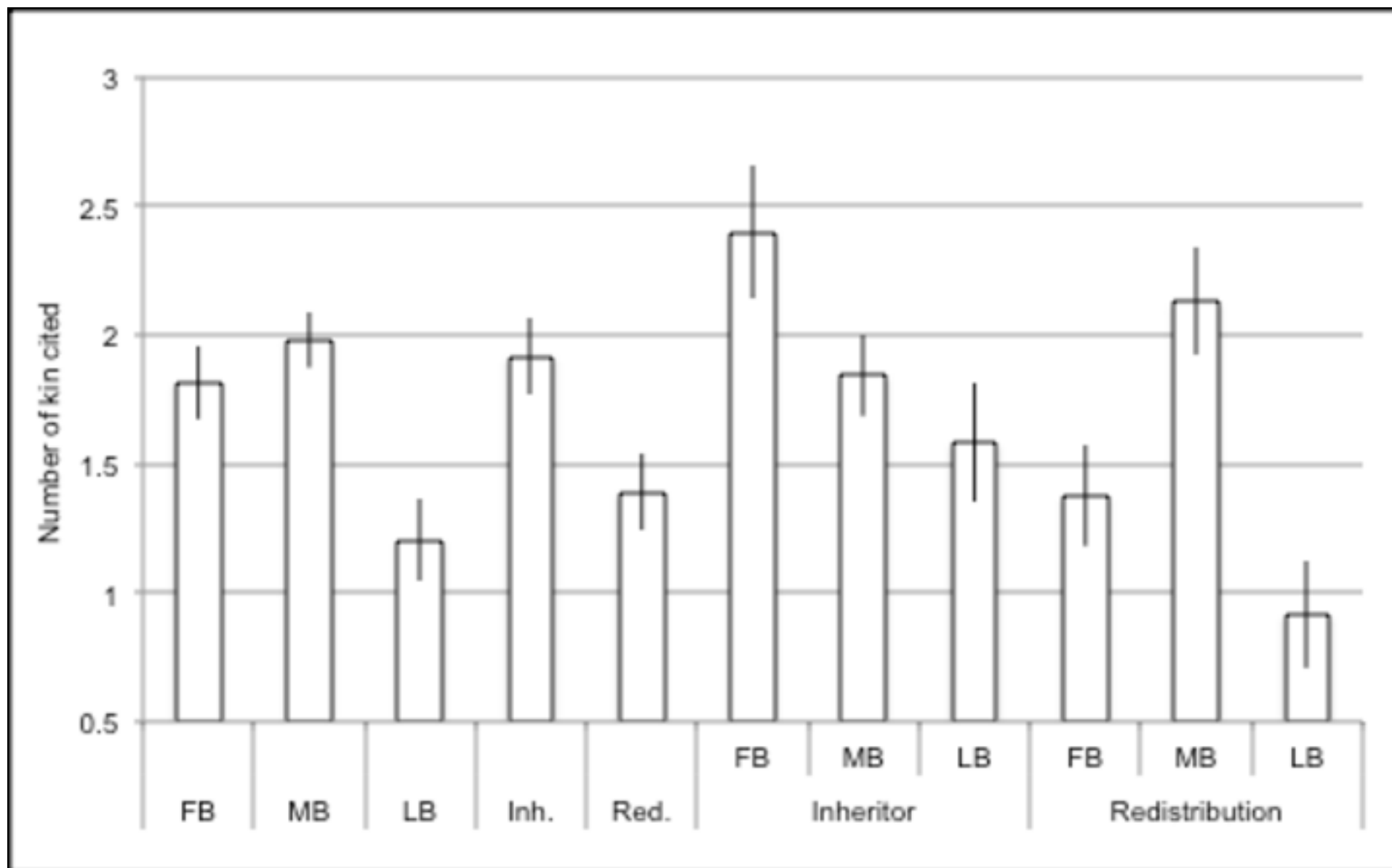
Table 4: GLMs with Poisson regression for the number of non-parental kin cited, non-parental kin and non-kin reciprocators for the two generational groups.

	Number of non-parental kin cited in support network					
	Inheritor group (n=180)			Redistribution group (n=151)		
	n	expB(95%CI)	P	n	expB(95%CI)	P
Intercept		2.2(0.7-7.1)	0.180		0.8(0.3-2.2)	0.654
Age of respondent (years)	180	1.0(1.0-1.0)	0.770	151	1.0(1.0-1.0)	0.662
Bo: middle-born(/first-born sons)	103/46	0.7(0.6-1.0)	0.062			
Bo: last-born(/first-born sons)	31/46	0.5(0.3-0.8)	0.003 **			
Bo: first-born (/middle-born sons)				48/79	0.6(0.5-0.9)	0.010 **
Bo: last-born (/middle-born sons)				24/79	0.5(0.3-0.8)	0.004 **
Number of male siblings	180	1.0(0.9-1.0)	0.621	151	1.0(0.9-1.1)	0.787
Land size(ha)	180	1.2(0.9-1.5)	0.196	151	0.9(0.8-1.1)	0.552
Village 1(/2)	105/75	1.1(0.8-1.4)	0.586	88/63	0.8(0.6-1.1)	0.201
High school education (not educated/educated)	145/35	0.9(0.6-1.2)	0.367	133/18	1.2(0.7-2.1)	0.388
Christians/Muslims	143/37	1.0(0.7-1.4)	0.900	134/17	1.8(1.0-3.1)	0.045 *
Land origin (not from family/from family)	19/161	0.7(0.4-1.1)	0.169	128/23	1.3(0.8-2.0)	0.238

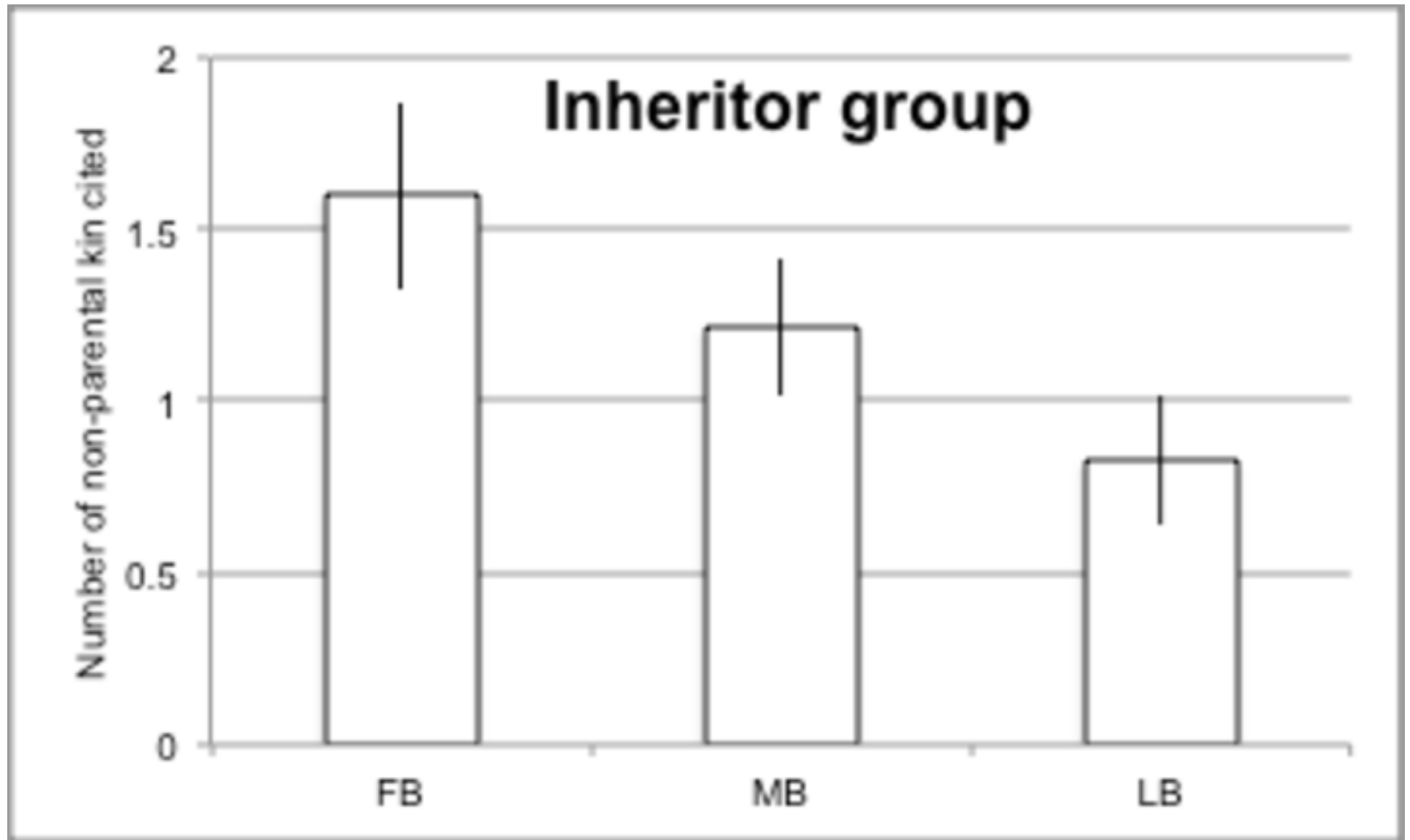
	Number of non-parental kin reciprocators in support network					
	Inheritor group (n=180)			Redistribution group (n=151)		
	n	expB(95%CI)	P	n	expB(95%CI)	P
Intercept		1.0(0.2-5.5)	0.958		0.3(0.1-1.6)	0.164
Age of respondent (years)	180	1.0(1.0-1.0)	0.690	151	1.0(1.0-1.0)	0.529
Bo: middle-born(/first-born sons)	103/46	0.9(0.6-1.4)	0.817			
Bo: last-born(/first-born sons)	31/46	0.7(0.4-1.3)	0.257			
Bo: first-born (/middle-born sons)				48/79	1.0(0.6-1.6)	0.924
Bo: last-born (/middle-born sons)				24/79	0.9(0.5-1.8)	0.814
Number of male siblings	180	0.9(0.8-1.0)	0.191	151	1.0(0.9-1.1)	0.846
Land size(ha)	180	1.0(0.7-1.3)	0.828	151	1.4(1.0-1.8)	0.027 *
Village 1(/2)	105/75	0.6(0.4-0.9)	0.018 *	88/63	0.5(0.3-0.8)	0.009 **
High school education (not educated/educated)	145/35	1.0(0.6-1.6)	0.935	133/18	0.3(0.2-0.7)	0.002 **
Christians/Muslims	143/37	1.1(0.6-1.9)	0.751	134/17	1.2(0.5-2.9)	0.625
Land origin (not from family/from family)	19/161	0.6(0.3-1.3)	0.229	128/23	2.0(1.0-4.2)	0.050 *

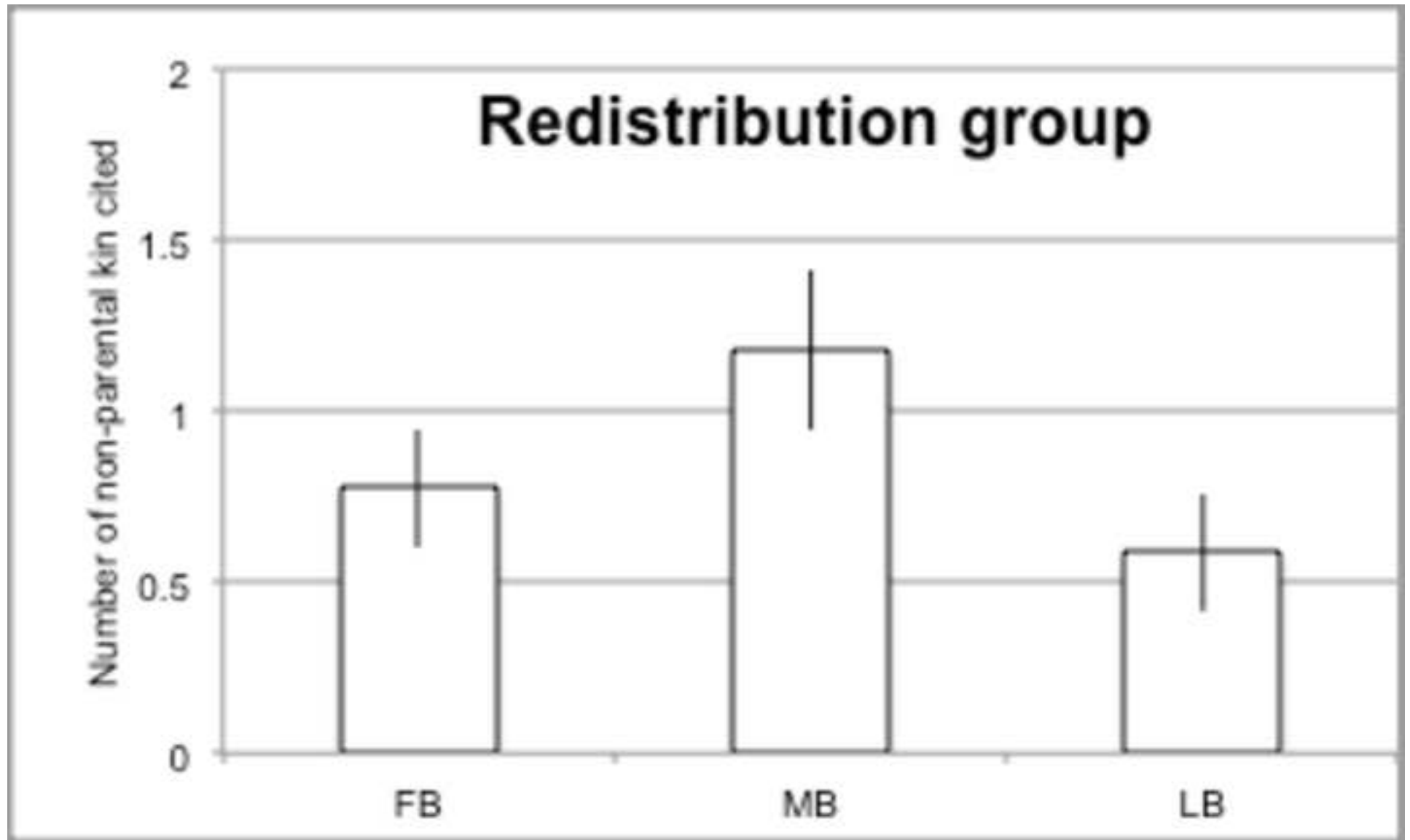
	Number of non-kin reciprocators in support network					
	Inheritor group (n=180)			Redistribution group (n=151)		
	n	expB(95%CI)	P	n	expB(95%CI)	P
Intercept		0.3(0.1-1.4)	0.131		4.2(1.3-113.8)	0.017 *
Age of respondent (years)	180	1.0(1.0-1.0)	0.426	151	1.0(1.0-1.0)	0.696
Bo: middle-born(/first-born sons)	103/46	1.5(1.0-2.2)	0.037 *			
Bo: last-born(/first-born sons)	31/46	1.6(1.0-2.6)	0.045 *			
Bo: first-born (/middle-born sons)				48/79	1.1(0.8-1.6)	0.508
Bo: last-born (/middle-born sons)				24/79	1.5(1.0-2.4)	0.055 .
Number of male siblings	180	1.0(0.9-1.1)	0.773	151	0.9(0.8-1.0)	0.050 *
Land size(ha)	180	1.1(0.8-1.4)	0.519	151	1.0(0.8-1.2)	0.752
Village 1(/2)	105/75	0.6(0.4-0.9)	0.004 **	88/63	0.4(0.3-0.6)	0.000 **
High school education (not educated/educated)	145/35	1.0(0.6-1.5)	0.943	133/18	1.2(0.6-2.2)	0.613
Christians/Muslims	143/37	1.7(1.0-2.9)	0.033 *	134/17	0.6(0.4-1.1)	0.123
Land origin (not from family/from family)	19/161	1.0(0.6-1.6)	0.890	128/23	0.8(0.5-1.3)	0.444

Notes: \* p=0.05 \*\*p=0.01









## Appendix- descriptive statistics

### **Does kin-selection theory help to explain support networks among farmers in South-Central Ethiopia?**

Lucie Clech<sup>1,2\*</sup>, Ashley Hazel<sup>3</sup>, Mhairi A Gibson<sup>1</sup>

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Sample	Variables	Mean	SD	Median	Min-max	N	Frequencies
Full sample	Full network size	3.34	1.38	3.00	0-7	331	
	Kin network size	1.82	1.51	2.00	0-7	331	
	Non-kin network size	1.52	1.46	1.00	0-6	331	
	Number of kin reciprocators	0.82	1.11	0.00	0-5	331	
	Number of non-kin reciprocators	1.02	1.35	0.00	0-5	331	
	Number of close-kin reciprocators	0.65	0.92	0.00	0-4	331	
	Number of distant-kin reciprocators	0.17	0.56	0.00	0-4	331	
	Number of non-reciprocal kin	1.01	1.41	0.00	0-6	331	
	Number of non-reciprocal non-kin	0.50	0.98	0.00	0-5	331	
	Number of non-reciprocal close-kin	0.81	1.22	0.00	0-6	331	
	Number of non-reciprocal distant-kin	0.20	0.51	0.00	0-4	331	
	Number of non-reciprocal kin helpers	0.41	0.75	0.00	0-3	331	
	Number of non-reciprocal non-kin helpers	0.27	0.63	0.00	0-3	331	
	Number of non-reciprocal close-kin helpers	0.30	0.63	0.00	0-3	331	
	Number of non-reciprocal distant-kin helpers	0.11	0.36	0.00	0-2	331	
	Age (years)	43.46	15.71	38.00	21-90	331	
	Land size (ha)	1.43	1.14	1.00	0.25-5	331	
	Sibling size	8.33	3.26	8.00	3-22	331	
	Male sibling size	5.00	1.97	4.00	3-15	331	
	BO categories					331	firstborns=65
						331	middleborns=233
						331	lastborns=33
	Male BO categories					331	first-born sons=94
					331	middle-born sons=182	
					331	last-born sons=55	
Village					331	village 1=193	
					331	village 2=138	
Generations					331	inheritors=151	
					331	redistribution recipients=180	
Land origin					331	have received land from family=184	
					331	have not received land from family=147	
Inheritor group	Number of kin cited	1.99	1.53	2.00	0-6	180	
	Number of non-kin cited	1.94	1.39	1.00	0-6	180	
	Number of kin reciprocators	0.99	1.17	1.00	0-5	180	
	Number of non-kin reciprocators	1.02	1.32	0.00	0-5	180	
	Number of close-kin reciprocators	0.78	0.96	1.00	0-4	180	
	Number of distant-kin reciprocators	0.21	0.61	0.00	0-4	180	
	Number of non-reciprocal kin	1.00	1.40	0.00	0-6	180	
	Number of non-reciprocal non-kin	0.47	0.89	0.00	0-4	180	
	Number of non-reciprocal close-kin	0.77	1.15	0.00	0-5	180	

	Number of non-reciprocal distant-kin	0.23	0.58	0.00	0-4	180
	Number of non-reciprocal kin helpers	0.40	0.74	0.00	0-3	180
	Number of non-reciprocal non-kin helpers	0.26	0.60	0.00	0-3	180
	Number of non-reciprocal close-kin helpers	0.28	0.58	0.00	0-3	180
	Number of non-reciprocal distant-kin helpers	0.13	0.39	0.00	0-2	180
	Number of non-parental kin network size	1.39	1.33	1.00	0-5	180
	Number of non-parental kin reciprocators	0.71	1.04	0.00	0-5	180
	Age (years)	31.48	4.42	32.00	21-40	180
	Male sibling size	5.07	2.00	5.00	3-13	180
	Land size (ha)	0.64	0.60	0.5	0.25-3.25	180
	Cited a parent					180 yes=99
						180 no=81
	Reported a parent helper					180 yes=57
						180 no=123
	Reported helping a parent					180 yes=94
						180 no=86
	Reported a reciprocating parent					180 yes=49
						180 no=131
	Have at least one alive parent					180 yes=157
						180 no=23
	Male Bo categories					180 first-born sons=46
						180 middle-born sons=103
						180 last-born sons=31
	High school education					180 high-school educated=35
						180 did not complete high-school=145
	Village					180 village 1=105
						180 village 2=75
	Religion					180 Christians=143
						180 Muslims=37
	Land origin					180 have received land from family=161
						180 have not received land from family=19
Redistribution group	Number of kin cited	1.63	1.48	1.00	0-7	151
	Number of non-kin cited	1.55	1.54	1.00	0-6	151
	Number of kin reciprocators	0.61	1.00	0.00	0-4	151
	Number of non-kin reciprocators	1.03	1.39	0.00	0-4	151
	Number of close kin reciprocators	0.48	0.85	0.00	0-4	151
	Number of distant kin reciprocators	0.13	0.48	0.00	0-3	151
	Number of non-reciprocal kin	1.02	1.43	0.00	0-6	151
	Number of non-reciprocal non-kin	0.53	1.08	0.00	0-5	151
	Number of non-reciprocal close-kin	0.85	1.29	0.00	0-6	151
	Number of non-reciprocal distant kin	0.17	0.41	0.00	0-2	151

Number of non-reciprocal kin helpers	0.42	0.75	0.00	0-3	151	
Number of non-reciprocal non kin helpers	0.28	0.68	0.00	0-3	151	
Number of non-reciprocal close kin helpers	0.34	0.68	0.00	0-3	151	
Number of non-reciprocal distant kin helpers	0.9	0.32	0.00	0-2	151	
Number of non-parental kin network size	1.44	1.33	1.00	0-6	151	
Number of non-parental kin reciprocators	0.60	1.00	0.00	0-4	151	
Age (years)	57.75	11.90	55.00	41-90	151	
Male sibling size	4.91	1.97	4.00	3-15	151	
Land size (ha)	2.38	0.88	2.5	0.25-5.00	151	
Male Bo categories					151	first-born sons=48 middle-born sons=79 last-born sons=24
High-school education					151	high-school educated=18 did not complete high school=133
Village					151	village 1=88 village 2=63
Religion					151	Christians=134 Muslims=17
Land origin					151	have received land from family=23 have not received land from family=128
Have at least one alive parent					151	yes=54 no=97

## **Response to the reviewers**

### **Does kin-selection theory help to explain support networks among farmers in South-Central Ethiopia?**

Lucie Clech<sup>1,2\*</sup>, Ashley Hazel<sup>3</sup>, Mhairi A Gibson<sup>1</sup>

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Dear Dr Lancaster,

It is with great pleasure that we received your message.

The bio-sketches were updated and included in a separate file, the line numbers were removed from the manuscript, and separated files were created for the images.

Kind regards,  
Lucie Clech

Dear Dr Clech,

Thank you very much for your careful revisions and response to the manuscript review.

You have ably met the editorial concerns and your manuscript entitled "Does kin-selection theory help to explain support networks among farmers in South-Central Ethiopia?" is ready for publication in Human Nature.

There are a few additional things I will need from you in order to ready the manuscript for copy-editing;

1. The revised manuscript in a clean format with no line numbers or embedded images. Please consult Springer Science Instructions for Authors available on Human Nature's website, so that you can have everything in order.
2. A biographical sketch of each author.
3. The signed Disclosure of Interest Form, which is also available on Human Nature's website, mailed or emailed to me. The lead author can sign for both after first getting confirmation and clearly so indicating on the form.

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Jane B. Lancaster

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