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Paternity Uncertainty or Male Dominance?

Paternal versus Maternal Grandmothers' Contribution to Children's Schooling in Sub-Saharan Africa

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Abstract

Objectives: Evolutionary theory predicts grandmothers to invest more in their daughters' children than in their son's children, because of higher likelihood of being genetically related to her daughter's children. However, most African cultures are characterized by male dominance, making it more profitable to invest in sons than in daughters. Here, the relative importance of paternal versus maternal grandmothers for children's schooling and how this grandmother gender effect varies across circumstances is studied.

Methods: The effect of grandmothers' gender on children's schooling is studied using multilevel logistic regression analysis on data for 896,073 children aged 7–15 living in 33 sub-Saharan African countries. We control for demographic and socio-economic factors at household and context level and study the role of circumstances with interaction analysis.

Results: Children living with a paternal grandmother have a higher chance of being in school than children living with a maternal grandmother. This difference is larger for boys, when the father is higher educated and when a grandfather is present. It is reduced when the mother is more highly educated.

Conclusions: Children living with a paternal grandmother are associated with better schooling outcomes relative to those living with a maternal grandmother. The advantage of living with a paternal grandmother is stronger for boys. Male dominance as a cultural factor seems to be more important for grandmother's investments than certainty about genetic relatedness. More education helps to draw grandmothers' investments towards one's children.

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1. Introduction

In recent years, several studies have paid attention to the importance of grandmothers for their grandchildren's well-being in sub-Saharan African (SSA) countries (e.g. Lachaud & Kobiané, 2017; Lu & Treiman, 2011; Parker & Short, 2009; Duflo, 2003; Schrijner & Smits, 2018a, 2018b). This is important, because in these countries extended household structures with three generations living under one roof are still common practice. Research has shown that in the SSA region in about 16% of households a grandmother is co-residing (Schrijner & Smits, 2018a). Intuitively, given the supposed strong bond between mothers and daughters, grandmothers are expected to help their daughters during their fertile ages, when they face the workload of raising multiple children (Coall & Hertwig, 2010; Hawkes, 2003, 2004; Sear & Mace, 2008). There is broad evidence that the presence of a grandmother increases the chances of children to go to school and reduces the chances that they suffer from stunting or premature mortality (Parker & Short, 2009; Schrijner & Smits, 2018a, 2018b; Sear & Mace, 2008; Zeng & Xie, 2014).

An important question that has not yet been answered well in this literature is whether the importance of SSA grandmothers for the well-being of their grandchildren is similar for grandmothers from mother's side and grandmothers from father's side. The classic grandmother hypothesis emphasizes the bond between mothers and daughters and supposes the maternal grandmother to be particularly important (Hawkes, 2003, 2004). Also arguments from evolutionary theory regarding paternity uncertainty point into this direction (e.g. Bishop et al., 2009; Euler & Weitzel, 1996; Laham et al., 2005). The uncertainty about genetic relatedness is smaller for maternal grandmothers than for paternal grandmothers. Mother's mother knows for certain that her daughter is her daughter and that her daughter's child is her grandchild. Father's mother is certain that her son is her son, but is less certain that her son's child is her grandchild, because the wife of her son may be unfaithful. Evolutionary theory therefore predicts maternal grandmothers to be more willing to invest in their grandchildren than paternal grandmothers.

Although this argument seems reasonable, empirical evidence does not unequivocally support it. Some studies show indeed stronger effects of the presence of maternal grandmothers (Sear, Mace, & McGregor, 2000; Voland & Beise, 2002), but others find no differences (Beise, 2005; Gibson & Mace, 2005), or even a more positive effect of the presence of paternal grandmothers (Borgerhoff Mulder, 2007; Sear, 2008). There are also indications that cultural differences play a role, with maternal grandmothers being more important in industrialized societies and paternal

grandmothers being more important in traditional societies (Coall et al., 2018; Kaptijn et al., 2013; Snopkowski & Sear, 2015). Many traditional societies are patriarchal oriented, with sons being considered more important than daughters. Men often own the land, have more rights and obtain more respect in society (Cooper, 2012; Giovarelli et al., 2013; International African Institute, 1950; Jütting et al., 2008; Richardson, 2004; Unicef, 2007). This could led grandmothers to invest more in their son's children than in their daughter's children, even though they are less sure that his children are genetically related to her.

A second potentially important factor is the role of socio-economic circumstances; it might make a difference whether the household is wealthy or poor. Strassmann (2011) found that under poor circumstances (Dogon in Mali) co-residence of a paternal grandmother was associated with a higher hazard of death of a grandchild by the age of five. One of the explanations given is that elderly grandmothers are net-consumers and therefore become competitors with their grandchildren in the resource-poor society of the Dogon. Strassmann (2011) also noticed that girls sometimes grow slower if they are living with a grandmother. These findings indicate that there are circumstances under which grandmothers' co-residence may have a negative impact on child well-being. Two hypotheses about the role of the circumstances may be of particular interest. The local resource competition hypothesis, which predicts paternal relatives to be more helpful to young children under wealthier circumstances. And the Trivers-Willard hypothesis, which predicts investments in the male lineage to be higher under resource-rich circumstances and investments in the female lineage to be higher under resource-poor circumstances (Hopcroft, 2005; Trivers, 1972; Trivers & Willard, 1973).

To find out to what extent these theoretical perspectives are correct, the effects of co-residence of paternal versus maternal grandmothers on the educational participation of their grandchildren are studied. Using a database with information on grandparental co-residence for 896,073 children in 33 SSA countries, the following research questions are answered:

- *To what extent and in what way does the effect of co-residing grandmothers on the educational participation of their grandchildren differs between paternal and maternal grandmothers?*
- *To what extent and in what ways does this difference between paternal and maternal grandmothers vary across circumstances?*

This study improves on earlier research in important ways. First, by conducting broad comparative research covering all SSA regions, which -- in comparison to the earlier local studies -- gives us the opportunity to draw more general conclusions. Second, by using schooling instead of health as outcome variable. Gaining insight into grandmothers' role regarding children's schooling has been conducted before (Parker & Short, 2009; Schrijner & Smits, 2018a), but no such study exists about the difference between paternal and maternal grandmothers. Focusing on education is important, as education is essential for building up human capital, increasing employment chances and stimulating economic growth (Lutz et al., 2008; UNESCO, 2014). Grandmothers interested in the well-being of their grandchildren can therefore be expected to use their resources to facilitate their grandchildren's schooling. Third, by focusing the analysis on grandmothers who co-reside in the household of their children and separate this situation from fostering – where the child lives with the grandmother without its parents being present (e.g. AIDS orphans, compare Hampshire et al., 2015) – a clearer picture of the role of lineage is obtained. Fourth, by including control factors at both the household and the context level and including interactions in the model, the role of the context is studied better than in earlier research and situation-specific insights are gained into how the difference between paternal and maternal grandmothers might vary across situations.

In the next section, a theoretical framework is presented from which hypotheses are derived. This framework includes, besides paternity uncertainty, many control factors at household and context level that are known or expected to influence the effect of grandmothers on children's schooling. Section 3 describes the dataset and methods in more detail. In section 4 the results are presented and analysed. Concluding remarks are given in section 5.

2. Theoretical background

In general grandmothers are thought to be good caretakers and expected to contribute in a positive sense to the success in life of their young grandchildren (e.g. Hawkes, 2004; Hrdy, 1999, 2009; Sear & Mace, 2008). In rural Gambia maternal grandmothers doubled the survival chances of a Mandinka child (Sear et al., 2000). In Ethiopia grandmothers had a positive effect on child survival by relieving their daughters of heavy domestic work. Non-reproductive maternal grandmothers in Ethiopia were positively associated with child height (Gibson & Mace, 2005). African children have significant higher odds of being in school when they are living with a

grandmother. The effect is especially strong for girls and when the mother is missing from the household (Parker & Short, 2009; Schrijner & Smits, 2018a).

Evolutionary theory has often been used to explain grandparental investment in general, and -- more specifically – differences in investment between the maternal and paternal grandmother (e.g. Bishop et al., 2009; Euler & Michalski, 2007; Laham et al., 2005). The *classic grandmother hypothesis* supposes the prolonged survival of women after their fertile ages to have developed as a positive trait during human evolution. It offers them the possibility to increase their own reproductive success by helping their children raising their children (Hawkes et al., 1997; Hawkes, 2004).

An additional expectation is that grandmothers would invest more in their daughters' children than in their son's children. This expectation is called the *confidence of paternity hypothesis* (Gaulin & Schlegel, 1980; Strassmann & Garrard, 2011). The idea behind this hypothesis is that grandparental investment depends on the likelihood of being genetically related to a certain grandchild. As is explained in Figure 1, this likelihood is higher for the maternal grandmother than for the paternal grandmother. Mother's mother knows for certain that her daughter is her daughter and that her grandchild is her descendant. For her there are no uncertain generational links (arrows 1a and 1b). Father's mother is also certain that her son is her son (arrow 2a). However she is less certain that her grandchildren are genetically related to her, because her son might be cuckolded by her daughter in law. There is thus one uncertain generational link (arrow 2b). According to the confidence of paternity hypothesis, because of this uncertainty regarding whether her son's children bear her genes, the paternal grandmother might be less willing to invest in her grandchildren than the maternal grandmother. The willingness to invest in her son's children is expected to further diminish when the paternal grandmother has grandchildren through her daughter as well. She might then invest more in the offspring of her daughter than in the children of her son, because there are no uncertain generational links.

[Figure 1 about here]

It remains to be seen, however, whether this genetic mechanism – if it exists – is strong enough to overcome the effect of cultural factors. Paternity uncertainty is reduced by the fact that human mating generally takes place in a family context, whereby both males and females give up

external mating opportunities in exchange for fitness gains through investments into long-run parental care (Gavrilets, 2012; Korn, 2000; Vyrastekova, Huisman, Mosha, & Smits, 2013). Many traditional societies are also patriarchal oriented, with sons being considered more important than daughters. This preference for sons over daughters appears for instance in restriction of land ownership to men, poor inheritance rights of women, restrictions on the possibilities of women to move freely in the public domain and difficulties experienced by them in filing claims through judicial systems (Cooper, 2012; International African Institute, 1950; Richardson, 2004; Unicef, 2007; Gündüz-Hosgör & Smits, 2008). The social dominance of males over females – and the social prestige associated with having sons – might make it more socially rewarding for grandmothers to invest in the offspring of her son(s) than her daughters, even though the genetic relatedness is less certain. Hence, according to the *male dominance hypothesis,* a positive effect of a co-residing grandmother on the schooling of her grandchildren will be stronger for her sons' children than for her daughters' children.

Besides paternity uncertainty and male dominance, a difference in effect between the paternal and maternal grandmother might also be influenced by socio-economic factors. The *local resource competition hypothesis* (e.g. Borgerhoff Mulder, 2007; Sear & Mace, 2008) emphasizes the negative effects on altruistic behaviour of family members due to scarcity of local resources. Borgerhoff Mulder (2007) observed, using within-population variation in land ownership in Kenya, that wealth affects the extent of kin altruism. Paternal relatives (specifically father's brothers) appear to buffer young children from mortality much more effectively in rich than in poor households. In line with this reasoning paternal grandmothers are expected to invest more in their (grand)children in rich households.

Another interesting perspective on the role of resources is the *Trivers-Willard hypothesis* (Hopcroft, 2005; Trivers, 1972; Trivers & Willard, 1973) which supposes grandparents to invest more in their sons under good socio-economic circumstances and in their daughters under bad circumstances. The explanation for this is that women prefer high status men over low status men when it comes to reproduction, whereas men in this respect are more indifferent in their choice. Under poor circumstances, low status men will therefore have fewer opportunities to marry, and if they find a partner it often will be one with less reproductive prospects. For low status women, the chances to marry are better, as high status men are less concerned about the status of their wife than high-status women. Under poor circumstances, it might be more attractive for a woman

to become the second or third wife of a wealthy husband than to be the first wife of a poor husband. Investing in daughters and their families might therefore be the best evolutionary strategy for (grand)parents in poor households, whereas investing in sons would be the best strategy for (grand)parents in wealthy households. Genetic theory also suggests sex-specific patterns in the investments of paternal versus maternal grandmothers (Coall & Hertwig, 2010; Fox et al., 2010). For example, due to the difference in X-chromosome inheritance between maternal and paternal grandmothers, girls are expected to profit more than boys of the presence of a paternal grandmother (Fox et al., 2010).

3. Data and methods

Data

Demographic and Health Survey data (DHS; www.dhsprogram.com) was combined in a new database with information on 896,073 children (456,265 boys and 439,808 girls) aged 7–15. These children are living in 29,925 local communities (sample clusters) within 1,164 sub-national regions of 33 countries. The data are derived from the Database Developing World (www.datdevworld.org). The data is supplemented with context information at the level of districts and clusters. Given the large sample size of the database, district and cluster variables could be created by aggregating data at household level. Because of missing cases on the variables parental education, (grand)parental age, polygamy, number of brothers and sisters, wealth, educational participation and some unrealistic cases for (grand)parental age, in total 21.730 (2,4%) children have been removed from the initial dataset of 917,788 children. Unrealistic cases are parents with an age below 19 or grandmothers aged below 31 (as the included children are at least aged 7). Structural missings on characteristics of parents and grandmothers who were absent from the household (e.g. education or occupation of a death father) are addressed using the dummy variable adjustment procedure, which leads to unbiased estimates of these variables (Allison, 2001; Little and Rubin, 2002). The appendix contains additional information about the sample, such as which countries are included in the data and the year in which the surveys were conducted. The response rates are generally very high, over 95% in most countries. All included DHS-surveys are dated after 2000, only for South Africa and Togo the included surveys were from 1998, because no later surveys were available for these countries.

Method and Variables

The relative importance of paternal versus maternal grandmothers and the effect on schooling is studied using multilevel logistic regression analysis. Three-level logistic regression analysis is used to address the nesting of the households within sample clusters and districts. To control for the nesting within countries fixed effects dummies at the national level are included. This strategy allows us to control for clustering and confounding at the national level while retaining the possibility to study the role of context factors at the district and cluster level. Multilevel regression analysis is the appropriate method to analyse such clustered data (Khan & Shaw, 2011). In the model the dependent variable comprises educational participation, which is a dummy variable indicating whether (1) or not (0) children aged 7–15 were attending school at the time of the interview. The upper age limit of 15 was chosen because above that age already a substantial number of children is not living with their parents anymore (e.g. because of early marriage, for educational reasons, or parental death). The lower age limit was set at 7 to avoid excluding children in countries where many children start schooling later than the compulsory age (Huisman & Smits, 2009). Because the dependent variable is dichotomous, it violates the assumption of a normal distribution of errors and of homoscedasticity for OLS regression (Allison, 1999; Pampel, 2000). Therefore, *logistic* regression models were applied. The models are estimated with MLwiN, using second-order penalized quasi-likelihood (PQL2), the recommended estimating technique for multilevel logistic regression analysis (Goldstein & Rasbash, 1996).

The major independent variable is a dummy variable that represents the difference between co-residing of a paternal grandmother and co-residing of a maternal grandmother (reference category). Households where one or both parent(s) of a male household head or of a male partner of the household head are living are considered patrilocal. Households where one or both parent(s) of a female household head or of a female partner of the household head are living, are considered matrilocal. Given the aim to study the difference between households with only a paternal grandmother and households with only a maternal grandmother, the focus of the analyses is on the dummy variable that represents the difference between living with a paternal grandmother compared to living with a maternal grandmother (reference category). In the rest of the paper, this variable will be called the *grandmother gender effect*.

When studying the size of this effect, the focus is on the more or less 'normal' situation where a grandmother co-resides in the household of (one of her) children. This situation is separated in the analysis from the situation of fostering, where a child is co-residing in the household of the grandmother without its parents being present. This separation is implemented by including an extra 'fostering' dummy for this situation. Finally, a small number of cases (317 or 0.01%) in which children were living together with both their paternal and maternal grandmother were left out of the analysis.

Next to the main independent variable, several other variables were included in the analyses to control for socio-economic and demographic factors at household and context level. Demographic factors at the household level that are taken into account are: the presence of parents, age and sex of the child, age of its parents and grandmother, birth order, number of brothers and sisters, presence of a grandfather. The presence of each parent is measured with two dummies, one indicating whether (1) or not (0) the parent is absent from the household and one indicating whether (1) or not (0) the parent is deceased. Birth order, age of the child, age of its parents and grandmother, and the number of brothers and sisters were measured by interval variables. The presence of a grandfather is also measured by a dummy variable.

Socio-economic control factors, at the level of the household, included in the analyses are: wealth, employment and education. Because income is lacking in the data, household wealth was measured by the International Wealth Index (IWI; Smits and Steendijk, 2014), a comparative asset-based wealth index. IWI indicates to what extent households own a basic set of assets, valued highly by people across the globe. Education of the mother, father and grandmother is measured in years of education completed. Occupation of the father is measured by three dummy variables: (1) Farm, (2) Lower non-farm (sales, services, manual), (3) Upper non-farm (professional, technical, managerial, clerical). Work status of the mother is a dummy variable indicating whether (1) or not (0) the mother was employed.

To control for the relative position of women at both household and context level, the age difference between husbands and wives was used. This age difference was measured as age mother minus age father. The smaller or more positive the age difference, the stronger the relative position of women is supposed to be. For the relative position of women in the context where the household lives, the average of the age difference between parents in the district as an interval

variable was used. The larger the age difference to the disadvantage of the women in the area, the weaker their position is considered to be.

Other context factors are urbanization, wealth, education and polygamy. Urbanization was measured by a dummy variable indicating whether (1) or not (0) the child lived in a rural area. The context level of development was measured as the mean International Wealth Index score of households in the cluster. Context education was measured by aggregating the variable years of education to the level of the DHS sample cluster. Kravdal (2006) shows that average cluster-level education can be effectively used to indicate context educational achievement. Mean years of education at cluster level is 2.94. The context variable polygamy is calculated as the percentage of polygamous households in the cluster.

To find out whether the grandmother gender effect differs according to the situation in which the household lives, interactions between the grandmother gender effect and the other independent variables in the model are studied. In this interaction analysis centred versions of these independent variables were used. The coefficients of the grandmother gender effect in the interaction model are thus for an average situation concerning the other variables. Given the explorative nature of the interaction analysis and the potentially large number of interactions, only significant interactions are included in the model. Children with a missing parent or grandparent were given the mean score of the other children on the (grand)parents characteristics. Because dummy variables were included, indicating whether (1) or not (0) the (grand)parent is missing, this procedure leads to unbiased estimates of these variables (Allison, 2001).

4. Results

In table 1 descriptive statistics of our sample are presented. In 16,2% of the cases children aged 7–15 are living with their grandmother of which 3,3% with their maternal grandmother and 4,6% with their paternal grandmother. In nearly 7% of the cases children are living with their grandfather. At the time of the interview 73% of the children were attending school. The average age of grandmothers in the sample amounted almost 63 years. For more than 23% of the children the mother is absent or deceased, whereas regarding fathers this accounts for 35% of the children. More than two third of the children is living in a rural area.

[Table 1 about here]

The results of the three-level logistic regression models are presented in Table 2. Model 1 contains only main effects. Model 2 contains main effects plus all significant interaction effects. The central variable in the models is the indicator for the *grandmother gender effect*, which measures the difference in educational participation between children in households with (only) a paternal grandmother and children in households with (only) a maternal grandmother (the reference category). The positive grandmother gender coefficients that can be observed in table 2 indicate that children in households with (only) a paternal grandmother have significantly higher odds of being in school. The effect is opposite to the prediction of the paternal uncertainty hypothesis: grandmothers seem to support the children of their sons more than those of their daughters. Compared to grandchildren living with a maternal grandmother, the odds of being in school are on average 19% higher for grandchildren living with their paternal grandmothers (Model 1).

The dummy for fostering shows a strong significant positive effect, thus indicating that in the generally more extreme situation that no parents are present – e.g. with aids orphans – it is particularly important that a child co-resides in the household of one of its grandmothers. Children without a grandmother in the household are worst off and have a significant lower chance of being in school than children in any of the situations with a grandmother.

The second aim of this study is to shed light on how the strength of the grandmother gender effect is moderated by varying circumstances. To test for this, interactions between the grandmother gender effect and all other household and context variables were estimated. Significant interactions were found with the gender of the child, parental education and the presence of a grandfather in the household. Model 2 includes all significant interactions. The grandmother gender effect is significantly stronger for boys than for girls. This difference is about 13% to the advantage of boys (odds ratio = 0.87 of interaction with sex). Hence the advantage of living with a paternal instead of a maternal grandmother is larger for boys than for girls.

[Table 2 about here]

Parental education is known to be an important factor in relation to children's schooling (Huisman & Smits, 2009). The interaction analysis makes clear that parental education is significantly associated with the grandmother gender effect. Interestingly, the grandmother gender effect is negatively related to maternal education and positively to paternal education. This implies that the advantage children have when living with a paternal grandmother becomes larger if their fathers are more highly educated. At the same time, this advantage is smaller when their mothers are more highly educated. The strength of these effects is almost similar. In both cases, an increase of parental education by one year is associated with a change of the grandmother gender effect of about 3%. In Figure 2, these interaction effects are depicted graphically.

[Figure 2 about here]

This figure shows that when the father has no education, the grandmother gender effect is close to zero. Indicating that there is no difference in effect on children's schooling between paternal and maternal grandmothers. As the educational level of the father rises, this has a positive impact on the grandmother gender effect: The higher the father's education, the more important the paternal grandmother is for children's schooling. A higher educational level of the mother on the other hand, pushes the grandmother gender effect into the opposite direction. It decreases towards zero and for highly educated mothers it may become even negative, indicating a more positive role for maternal grandmothers compared to paternal grandmothers with respect to children's schooling.

The last significant interaction effect is with the presence of a grandfather in the household. Given that there are very few cases in the data (only 0.01% of households with a grandmother) where both a paternal grandmother and a maternal grandfather or a maternal grandmother and a paternal grandfather are living in the same household, the co-resident grandfather is in almost all cases the husband of the grandmother. The presence of a grandfather significantly strengthens the grandmother gender effect, thus indicating that the combination of a paternal grandmother with the paternal grandfather is particularly favourable for children's schooling.

5. Conclusion

According to the classical grandmother hypothesis the prolonged survival of women after their fertile ages has developed during human evolution because it offers them the possibility to increase their own reproductive success by helping their daughters raising their children (Hawkes, 2004; Hawkes et al., 1997). The expectation that they would invest more in their daughters' children is based on the so called confidence of paternity hypothesis. Grandparental investment is supposed to depend on the likelihood of being genetically related to a certain grandchild, which is more certain for maternal than for paternal grandmothers. This hypothesis was tested against several other hypotheses, including the male dominance hypothesis which predicts the effect of a co-residing grandmother on the schooling of her grandchildren to be more positive for her son's children than for her daughter's children. As discussed in Section 2, many regions of Africa are characterized by a patriarchal culture in which men, sons and grandsons are considered to be more important than women, daughters and granddaughters (Giovarelli et al., 2013; Jütting et al., 2008; Kandiyoti, 1988). In such a culture, the effect of genetic relatedness – if it exists – might easily be overruled by the greater societal importance attached to male offspring. Two other – resource related – hypotheses tested in this paper are the local resource competition hypothesis, which predicts paternal relatives to be more helpful to young children under wealthier circumstances and the Trivers-Willard hypothesis, which predicts investments in the male lineage to be higher under resource-rich circumstances and investments in the female lineage to be higher under resource-poor circumstances.

To test these hypotheses, the importance of co-residing maternal and paternal grandmothers for the educational attendance of young (aged 7-15) SSA children was studied by applying multilevel logistic regression analysis on data for 896,073 children in 33 sub-Saharan African (SSA) countries. This analysis did not provide any support for the confidence of paternity hypothesis. In fact the opposite effect was observed. Children living with their paternal grandmother are associated with better schooling outcomes relative to those who are living with their maternal grandmother. This result is in line with the prediction of the male dominance hypothesis and suggests that the preference for sons over daughters in the SSA context is so strong that grandmothers tend to favour their son's children over their daughters children even though the genetic relatedness of their son's children is less certain.

The importance of male dominance is further supported by two additional outcomes of the interaction analysis. First, it was found that the grandmother gender effect is particularly strong for boys. This implies that grandmothers not only invest more in their son's children than in their daughter's children, but also that they invest more in their son's sons than in their son's daughters. Second, the observation that the presence of a grandfather more or less doubles the grandmother gender effect. Given that in almost all cases that grandfather is the husband of the grandmother, this indicates that grandfathers have an equally strong tendency as grandmothers to invest more in the children of their sons than in the children of their daughters.

The interaction analysis further revealed that the grandmother gender effect depends on the educational level of both parents. The interaction effects with father's and mother's education have about the same strength, but work in opposite directions. Father's education strengthens the grandmother gender effect and mother's education weakens this effect. This means that the tendency of grandmothers to invest in the children of their sons or their daughters is also influenced by the resources in the form of human capital those sons and daughters have at their disposal. If their sons have more human capital their investments go more into the direction of their sons children and if their daughters have more human capital they invest relatively more the children of their daughters.

No significant interaction was found between the grandmother gender effect and household wealth. This suggests that the effect does not depend on the financial resources of the household. Hence neither the resource competition hypothesis nor the Trivers Willard hypothesis is supported by the findings.

Ethical Approval

This research is entirely based on existing data obtained from the Demographic and Health Survey (DHS) program. The team executing the DHS program ensures protection of human subjects in agreement with local and international laws.

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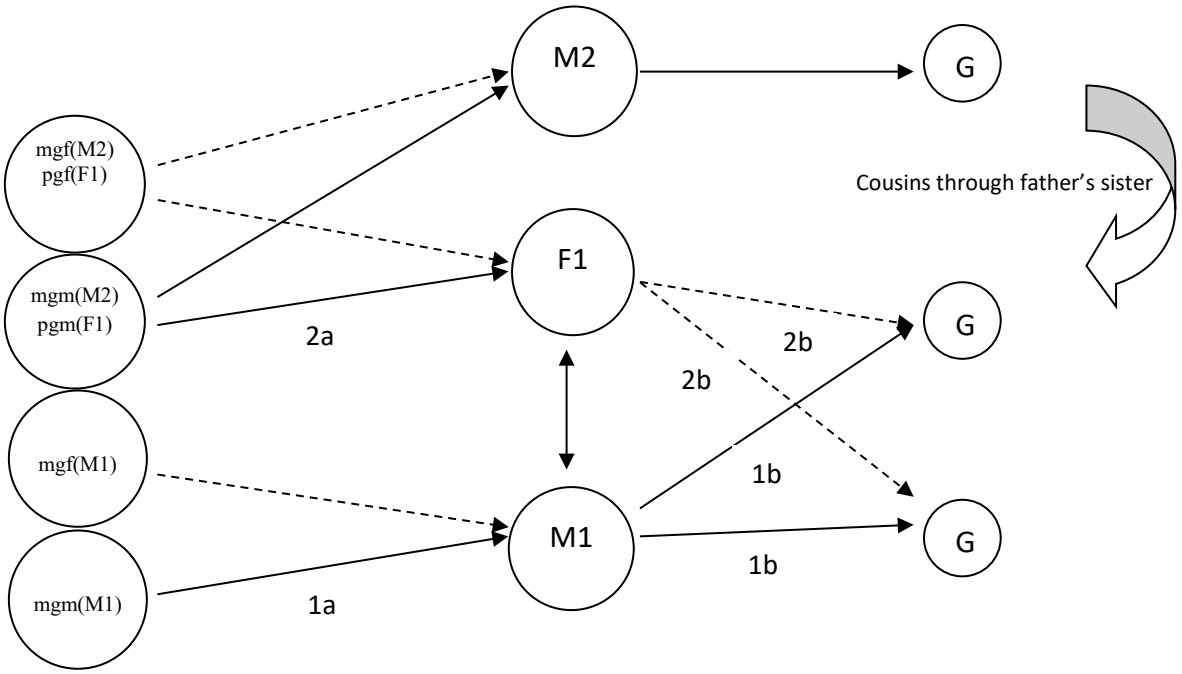
Figure 1 Paternity uncertainty and genetic relatedness



Maternal/Paternal Grandmother/Grandfather (mgm/pgm/mgf/pgf), Mother/Father (M/F), Grandchild (G). Dashed lines: uncertain generational links.

Figure 2 Predicted grandmother gender effect and level of education parents

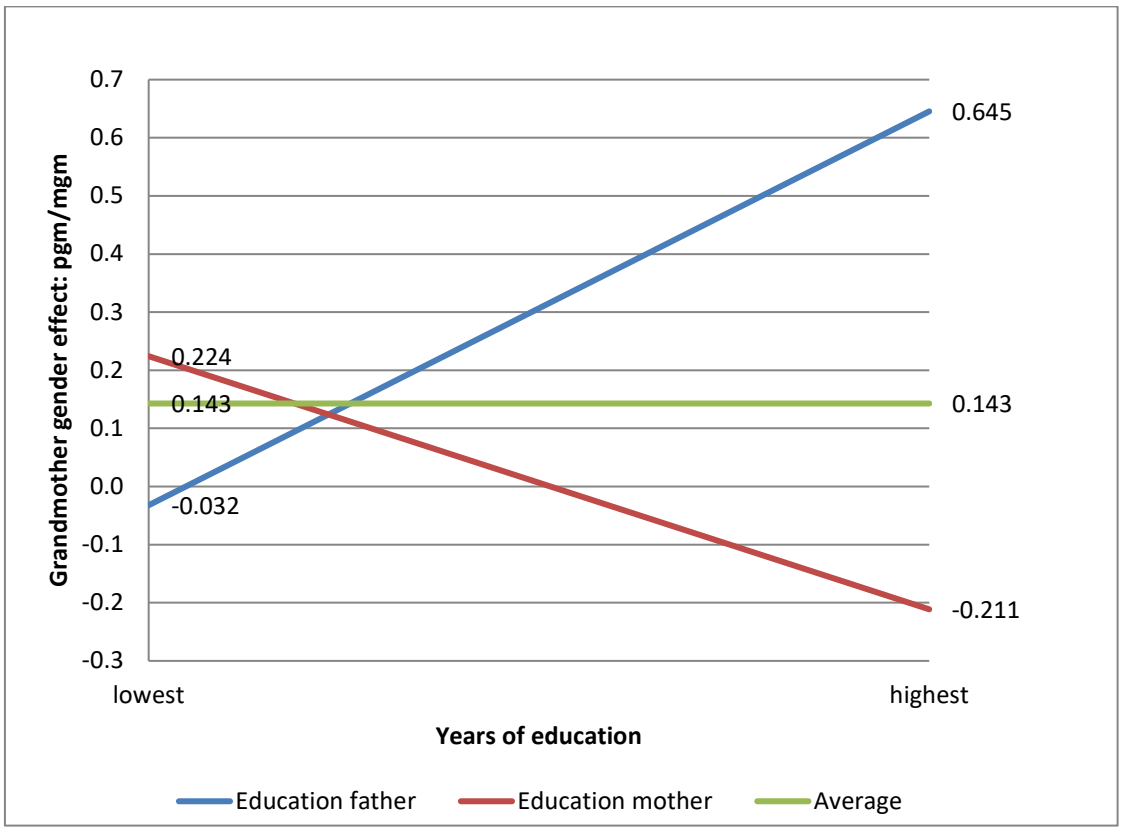


Table 1 Descriptive statistics: Percentages, means of characteristics of children aged 7-15

Variables	%, mean	min	max	SD
School attendance	73.0%	0	1	0.44
Co-residential status grandmother				
Maternal grandmother co-resident	3.3%	0	1	0.18
Paternal grandmother co-resident	4.6%	0	1	0.21
Fostering (both parents absent)	8.3%	0	1	0.28
No grandmother in household	83.8%	0	1	0.37
Demographic factors at household level				
Age child	10.67	7	15	2.54
Sex of child (boy=0, girl=1)	49.0%	0	1	0.50
Age mother	37.90	19	65	7.26
Age father	46.94	19	97	8.82
Age grandmother	62.90	31	97	4.36
Birth order child	3.30	1	18	1.94
Number of sisters	1.92	0	10	1.65
Number of brothers	2.04	0	10	1.73
Mother alive, not in household	19.0%	0	1	0.39
Mother deceased	4.4%	0	1	0.20
Father alive, not in household	25.9%	0	1	0.44
Father deceased	9.5%	0	1	0.29
Grandfather co-resident	6.8%	0	1	0.25
Socio-economic factors at household level				
International Wealth Index (IWI)	26.97	0	100	22.74
Education father (years)	4.13	0	16	3.79
Education mother (years)	2.99	0	16	3.47
Education grandmother (years)	1.48	0	16	1.14
Occupation father (ref.=farm):	60,4%	0	1	0.49
Lower non-farm	29,5%	0	1	0.46
Upper non-farm	10,1%	0	1	0.30
Mother employed	69.3%	0	1	0.46
Relative position women (age mother – age father)	-9.40	-70	41	6.05
Socio-economic/Cultural factors at context level				
Living in rural area	70.7%	0	1	0.46
International Wealth Index (district)	27.02	0.99	88.96	16.93
Relative position women (age mother – age father, district)	-8.99	-27.14	0.04	2.64
Educational level (cluster)	2.94	0	12.5	1.30
Polygamy (district)	0.29	0	1	0.19

Source: Demographic and Health Surveys

Table 2 Coefficients of multilevel logistic regression models and the log odds of being in school as dependent variable (odds ratios between brackets)

	Model 1	Model 2
Grandmother gender effect (ref=maternal grandmother)	B (odds ratio)	B (odds ratio)
Grandmother gender effect *average*	**.171***(1.19)**	**.143***(1.15)**
Grandmother gender effect *girls*		**.072 (1.07)**
Grandmother gender effect *boys*		**.211*** (1.24)**
Fostering (both parents absent)	.462***(1.59)	.472***(1.60)
No grandmother in household	-.079**(0.92)	-.086**(0.92)
Interactions with grandmother gender effect		
Grandmother gender effect * Sex		-.139***(0.87)
Grandmother gender effect * Education mother		-.027** (0.97)
Grandmother gender effect * Education father		.042***(1.04)
Grandmother gender effect * Grandfather co-resident		.165***(1.18)
*Demographic and socio-economic **control factors** at household level*		
Age child	.029*** (1.03)	.029*** (1.03)
Sex of child (boy=0, girl=1)	-.249***(0.78)	-.247***(0.78)
Age mother	.039***(1.04)	.039***(1.04)
Age mother square	-.0004***(1.00)	-.0004***(1.00)
Age grandmother	.005***(1.05)	.005***(1.05)
Age grandmother square	-.0003***(1.00)	-.0003***(1.00)
Birth order child	-.024***(0.98)	-.024***(0.98)
Number of sisters	.009*** (1.01)	.009*** (1.01)
Number of brothers	-.025***(0.98)	-.025***(0.98)
Mother absent	-.571***(0.57)	-.571***(0.57)
Mother deceased	-.642***(0.53)	-.640***(0.53)
Father absent	-.323(0.72)	-.323(0.72)
Father deceased	-.350*(0.71)	-.348*(0.71)
Grandfather co-resident	-.056**(0.95)	.077*(1.08)
International Wealth Index (IWI)	.027***(1.03)	.027***(1.03)
Education father (years)	.079***(1.08)	.075***(1.08)
Education mother (years)	.086***(1.09)	.087***(1.09)
Education grandmother (years)	.080***(1.08)	.079***(1.08)
Occupation father, lower non-farm *(ref=farm)*	.114***(1.12)	.115***(1.12)
Occupation father, upper non-farm *(ref=farm)*	.221***(1.25)	.221***(1.25)
Mother employed	.142***(1.15)	.142***(1.15)
Relative position women (age mother – age father)	.004***(1.00)	.004***(1.00)
*Socio-economic **control factors** at context level*		
Living in rural area	-.522***(0.59)	-.522***(0.59)
International Wealth Index (district)	-.014***(0.97)	-.014***(0.99)
Relative position women (age mother – age father, district)	.024 (1.02)	.024 (1.02)
Educational level (cluster)	.148***(1.16)	.148***(1.16)
Polygamy (district)	-1.79***(0.17)	-1.79***(0.17)
Year of survey	.050***(1.05)	.050***(1.05)

***P<0.001, **P<0.01, *P<0.05. (n=896,073 of which 145,022 is living with a grandmother and 654,136 is attending school)

Appendix DHS country data, year of survey(s) and household response rates

Country	**Year(s)**	**HH Resp. rate (%)**
Benin	2001, 2006, 2011	97.0, 99.1, 98.6
Burkina Faso	2003, 2010	99.4, 99.2
Burundi	2010	99.1
Cameroon	2004, 2011	97.6, 99.0
Chad	2004	99.4
Cote d'Ivoire	2005, 2011	95.5, 98.1
Congo DR	2007, 2013	99.3, 99.9
Congo Brazzaville	2005, 2011	99.2, 99.8
Ethiopia	2000, 2005, 2011	99.3, 98.5, 98.1
Gabon	2000, 2012	97.6, 99.3
Ghana	2003, 2008	98.7, 98.9
Guinea	2005, 2012	99.2, 99.5
Kenya	2003, 2008	96.3, 97.7
Lesotho	2004, 2010	95.2, 97.6
Liberia	2007, 2013	97.2, 99.4
Madagascar	2004, 2009	97.8, 98.8
Malawi	2000, 2004, 2010	99.0, 97.8, 98.1
Mali	2001, 2006, 2013	97.9, 98.8, 98.4
Mauritania	2001	98.4
Mozambique	2003, 2011	80.6, 99.8
Namibia	2000, 2006, 2013	96.9, 97.8, 96.9
Niger	2006, 2012	98.0, 98.0
Nigeria	2003, 2008	98.6, 98.3, 99.0
Rwanda	2000, 2005, 2010	99.7, 99.7, 99.8
Senegal	2005, 2011, 2012	98.5, 98.4, 98.7
Sierra Leone	2008, 2013	97.6, 99.3
South Africa	1998	97.0
Swaziland	2006	95.2
Tanzania	2004, 2010	98.8, 98.8
Togo	1998	98.6
Uganda	2001, 2006, 2011	95.8, 95.3, 97.5
Zambia	2002, 2007	98.2, 97.8
Zimbabwe	2006, 2011	95.0, 96.0