J.biosoc.Sci, page 1 of 25, © 2008 Cambridge University Press
doi:10.1017/S0021932009003307

LINEAGE BASED DIFFERENCES IN GRANDPARENTAL INVESTMENT: EVIDENCE FROM A LARGE BRITISH COHORT STUDY

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Summary. Evolutionary theory suggests that maternal grandparents will invest more in their grandchildren than paternal grandparents, due to the difference between the certainty of maternity and the uncertainty of paternity. Most tests of this prediction have tended to use retrospective ratings by grandchildren rather than examining grandparental behaviour. Using a large-scale data set from the UK (n>7000), significant differences are shown between maternal and paternal grandparents in terms of frequencies of contact with their newborn grandchildren, while controlling for a wide range of other variables. Maternal grandparents also provided a significantly wider range of financial benefits than paternal grandparents. Maternal grandparents were also more likely to provide essentials and gifts and extras for the baby. Multiple correspondence analysis showed that contact frequencies systematically related to other measures of grandparental investment, indicating that contact frequencies are a useful proxy measure to examine overall investment. Findings are discussed with reference to the paternity uncertainty hypothesis.

Introduction

Kinship has been claimed to be of relatively low importance for social interaction in modern societies (Giddens, 1991; Beck, 1993; Beck & Beck-Gernsheim, 2002). However, from an evolutionary perspective, biological relatedness would be expected to be an enduringly powerful determinant of social investments, even in modern societies (Hamilton, 1964). In support of this, in historical European populations, grandmothers have been found to provide significant benefits for their grandchildren (Lahdenperä *et al.*, 2004; Ragsdale, 2004). Similar beneficial effects were found for contemporary populations in rural Ethiopia, Gambia and Tanzania (Hawkes *et al.*, 1997; Sear *et al.*, 2000, 2002; Gibson & Mace, 2005). It appears that for humans, grandmothers may have a strong impact on their grandchildren's fitness and hence their own inclusive fitness (Mace & Sear, 2005; Sear & Mace, 2008). These fitness benefits, in combination with other traits, could potentially explain the evolution of

a long postmenopausal lifespan in women (for example: Hawkes *et al.*, 1998; Shanley & Kirkwood, 2001; Shanley *et al.*, 2007, but see Cant & Johnstone, 2008). Grandfathers, by contrast, appear to have little impact on the fitness of their grandchildren (for example: Blurton-Jones *et al.*, 2005; Lahdenperä *et al.*, 2007; Sear & Mace, 2008). There appears to have been little selection pressure for a post-reproductive lifespan in men.

From an evolutionary psychological perspective one would predict, however, that lineage as well as sex of the grandparent will influence the level of grandparental investment. All else being equal, maternal grandparents will invest more in their grandchildren than paternal grandparents, because maternal grandparents are related to their grandchildren by certain maternity rather than uncertain paternity. Consistent with predictions based on paternity uncertainty, differences in solicitude between maternal and paternal grandparents have been found in historical (Voland & Beise, 2002), ethnographic (Sear *et al.*, 2000, 2002) and industrial societies (Euler & Weitzel, 1996; Euler *et al.*, 2001; Michalski & Shackelford, 2005; Pashos & McBurney, in press). These studies find that maternal grandmothers tend to invest most in their grandchildren, followed by maternal grandfathers, and paternal grandmothers, with paternal grandfathers investing least (Kahana & Kahana, 1970; Hoffman, 1979–1980; Eisenberg, 1988; Rossi & Rossi, 1990), even though paternity uncertainty in contemporary societies is assumed to be relatively low (see Anderson, 2006). Similar differences between matrilines and patrilines have also been documented for uncles and aunts (Gaulin *et al.*, 1997; McBurney *et al.*, 2002). In general, individuals thus appear to invest more in their matriline than in their patriline. We argue that such differential investment can be ultimately explained by evolved psychological mechanisms attuned to paternity uncertainty (see Euler & Weitzel, 1996). Yet, the degree to which these psychological mechanisms are expressed and lead to measurable differences in investment between the maternal and paternal lineage depends on local ecologies, such as the factual degree of paternity uncertainty in a given population, for example (see McBurney *et al.*, 2002).

Pashos (2000), however, found the reverse pattern for rural Greeks: paternal grandparents invested more than maternal grandparents in their grandchildren. Similar effects have been found for rural areas in the USA (King & Elder, 1995; King *et al.*, 2003). A possible explanation for this effect is that in rural samples inheritance of land benefits males and females differently and that solicitude measures reflect attempts by males to acquire land from grandparents, rather than grandparental investment (Michalski & Shackelford, 2005).

Evolutionary studies of grandparental investment in modern societies have mainly focused on retrospective ratings by grandchildren, rather than grandparental behaviour (Euler & Weitzel, 1996; Pashos, 2000; Euler *et al.*, 2001; Laham *et al.*, 2005; Pashos & McBurney, in press; but see Michalski & Shackelford, 2005; Chrastil *et al.*, 2006; Pollet *et al.*, 2006, 2007). The main argument for using this method has been that grandparents would give socially desirable answers and therefore would claim to treat all grandchildren equally (Hoffman, 1979–1980; Euler & Weitzel, 1996). However, research from a family studies perspective has found consistent differences in grandparent–grandchild contact frequencies by lineage (Uhlenberg & Hamill, 1998). This suggests that grandparental behaviour can be examined by investigating

contact frequencies. Michalski & Shackelford (2005) have argued, however, that contact frequencies are a poor measure for investment, mainly because they do not take into account who initiates contact. Yet, social network research commonly uses contact frequency measures and these measures often relate to emotional and financial support (for example: Taylor, 1986; see House *et al*., 1988, for review). It is thus reasonable to examine contact frequency data from a grandparent perspective for evidence of lineage-based differences, as shown in previous studies (Pollet *et al*., 2006, 2007). Here, a large data set from the UK is analysed for lineage effects on contact frequency and grandparental investment. Marital separation of the grandparents, age and educational attainment of the mother and father, age of the infant and marital status of the mother are controlled for.

The chief prediction of interest is that, when other factors are controlled for, there will be consistent differences in contact frequency between maternal grandmothers and paternal grandmothers/grandfathers, and between maternal grandfathers and paternal grandfathers. However, paternity uncertainty does not necessarily lead to predict that maternal grandfathers will invest more than paternal grandmothers, as is commonly found. This finding has been attributed to co-residence of grandparents (see Gaulin *et al*., 1997; McBurney *et al*., 2002, but see Euler & Weitzel, 1996) or sex-specific investment in matrilines (Euler & Weitzel, 1996; Euler & Michalski, 2007). Laham and colleagues (2005) explained higher investment by maternal grandfathers than paternal grandmothers in terms of the availability of more certain 'outlets'. If alternative investment options (e.g. cousins via a sister) are available to paternal grandmothers, they should invest less in grandchildren than maternal grandfathers do.

Differences between maternal grandmothers and paternal grandmothers and between maternal grandfathers and paternal grandfathers would thus suggest that psychological mechanisms attuned to paternity uncertainty are operating. Differences between maternal grandfathers and paternal grandmothers can be explained by co-residence of grandparents, sex-specific investment strategies or available investment outlets. In summary, differences in face-to-face contact and investment according to the paternity uncertainty hypothesis are predicted. Moreover, this study aims to test whether or not contact frequencies positively relate to other measures of grandparental investment. If contact frequencies do relate to financial investment, then they can be used as a reliable proxy for financial investment. The study sample is very large compared with previous tests on the paternity uncertainty hypothesis (e.g. Euler & Weitzel, 1996) and allows thorough investigation of these issues.

Methods

Sample description and variables

The Millennium Cohort Study is a nationally representative study on pregnancy and child development (CLS, 2003; Plewis & Ketende, 2006). It contains data on 18,819 children born in the UK between 2000 and 2002 (Hansen, 2006). The response rate was 68% and the data presented below are from the first survey wave when the children were between nine and twelve months old. The sample is disproportionately stratified and ethnic minorities as well as respondents from deprived areas were

over-represented in this sample in comparison to the general population (see Hansen, 2006, for details). Cases where the respondents of the interviews were not the parents of the cohort member were excluded. Only cohort members for which all four grandparents were alive at the time of the survey and for which the contact frequency details where known were included. Homosexual parent couples were excluded from the analyses, as were parent couples where the male partner did not reside in the same household as the mother. Exclusion of couples where the male partner did not reside with the mother rules out that the lack of investment by paternal grandparents is due to factual separation of the parents (see Johnson, 1988). Also, only grandparents who had never separated were included. This rules out any effects based on grandparental marital status (Denham & Smith, 1989; Baydar & Brooks-Gunn, 1998; King, 2003; Reitzes & Mutran, 2004). The final sample consisted of 7469 individuals.

During the computer-assisted personal interview, parents of the cohort member reported how often they saw their parents. The question in the interview was 'How often do you see your mother/father nowadays?' (CLS, 2003). This item had nine response categories ('Every day', '3–6 times a week', 'once or twice a week', 'less often but at least once a month', 'once every few months', 'once a year', 'never' and 'parent lives with me'). There were only three respondents for which there were no data on these response variables (two for maternal grandmother and one for the maternal grandfather). These cases were excluded for analyses involving contact frequency. The category 'every day' was combined with 'parent lives with me'. Cases where the respondent answered 'the parent lives with me' were not common (less than 2·5% of the sample). The conclusions presented remain unaltered if these cases are excluded. Difference scores were calculated for this contact frequency measure between the four grandparents. A large score thus indicates that there is a large difference between grandparents in contact frequency.

Respondents also reported whether the birth of their child changed how often their mother and father had contact with them (three categories: 'more often', 'about the same as before', 'less often'). As for the contact frequency variable, difference scores between the four grandparent categories were calculated.

During the interview the respondent and her partner also provided information on whether their parents provided any financial benefits towards the child. If the respondent answered 'yes' to the question that their parents provided help, they were then asked: 'in what ways do they help you?' (CLS, 2003). The respondents' answers were subsequently coded into six categories: essentials for the baby, household costs, gifts and extras for the baby, loans and help for childcare and other financial help. The category 'other financial help' mainly consisted of buying or paying for large capital items (1); giving money or cash gifts (2); trust fund or savings account for the baby (3). Given that less than 0·5% of the sample listed that their parents provided 'other financial help', this category was discarded. The survey did not further differentiate whether their father or mother provided these benefits, so it was not possible to distinguish between maternal grandmothers and maternal grandfather or between paternal grandmothers and paternal grandfathers, only between the two lineages (maternal versus paternal grandparents). Two types of measures were constructed. Firstly, the sum of the different provided benefits was computed. This measure is referred to as the diversity index. Subsequently, a difference score between

maternal and paternal grandparents was calculated. A larger score indicates that the maternal grandparents offer financial benefits in a more diverse way than paternal grandparents. Secondly, difference scores for each type of benefit according to lineage was also calculated (essentials, household costs, gifts and extras for the baby, loans and help for childcare). These scores can be -1 (paternal grandparents provide this benefit but maternal grandparents did not), 0 (no difference between maternal and paternal grandparents) or 1 (maternal grandparents provide this benefit but paternal grandparents did not).

As control variables, educational attainment of the respondent and her partner as well as their ages, the age of the infant (in months) and the marital status of the mother were included. These factors have been shown to influence the relations between grandparents and their grandchildren (Kivett, 1985; Johnson, 1988; Denham & Smith, 1989; Baydar & Brooks-Gunn, 1998). Unfortunately no data on urbanization, distance between grandparent and parent, frequency of telephone contact between parent and grandparent, age and educational attainment of the grandparents or initiation of contact (Does the grandparent or the parent initiate contact?) are available. These useful controls are lacking (see Barranti, 1985; Lawton *et al*., 1994; King & Elder, 1995; Baydar & Brooks-Gunn, 1998; Uhlenberg & Hamill, 1998; King, 2003; Michalski & Shackelford, 2005). Nonetheless, even without these controls the data can be used to test whether there are lineage-based differences in grandparental contact and investment. Moreover, these data have some additional benefit over the previous set that we used (Pollet *et al*., 2006, 2007) as the grandchildren are all aged between nine and twelve months, and age of the grandchild has been shown to influence grandparental investment (Kivett, 1985). In addition, these data allow the investigation of whether the birth of a grandchild leads to differential investment by the grandparent. Moreover, previous research did not distinguish between types of financial investment.

Statistical analyses

Difference scores (contact frequency, change in contact after birth, financial help) are tested against zero by use of *t* tests. If difference scores are indeed significantly different from zero, then there are significant differences according grandparent type. Cohen's *D* was also calculated for this difference (Cohen, 1988).

In order to ensure that any significant differences found are not due to a spurious relationship with a third variable, the effects of control variables (age, marital status, educational attainment of the respondent, age of the infant in months, age, and educational attainment of the respondent's partner) on the difference scores are tested for using linear mixed models in SPSS 15·0. Linear mixed models take into account correlated effects between variables, as are found here (age of mother, age of father and educational attainment of mother and educational attainment of the father). Models with random effects (slopes and intercepts) at household level are also tested. The final models were selected based on Akaike Information Criterion (AIC) and Schwarz's Bayesian Information Criterion (BIC) (see Kuha, 2004). In all cases, the final 'best fit' models did not contain a random slope or intercept and all models presented differed minimum two units in AIC and BIC from the second-best models. The models had absolute parameter, likelihood and Hessian convergence (SPSS,

2005). The parameters in the final models were estimated by REML, as this method deals better with outliers than Maximum Likelihood (see Diggle, 1988). For the final models, a brief summary of F tests is presented. The F tests are used to examine whether a variable significantly contributes to the model. The effects of control variables in these models are not discussed in detail here, since the only concern is whether there is a difference by lineage that persists when other variables are controlled for. Parameter estimates for these variables can be obtained from the authors. If the residuals from the linear mixed models with control variables included are larger than zero, then the control variables do not entirely explain the observed differences. These residuals are tested against zero by use of the correspondent Wald Z test. It is important to bear in mind that residuals are absolute residuals.

Finally, whether contact frequencies relate to investment will be tested by use of multiple correspondence analysis (MCA) for each lineage (Clausen, 1998). Multiple correspondence analysis is a categorical equivalent to factor analysis and allows testing whether variables can be clustered together as an underlying dimension. The explained inertia (MCA labels variance as inertia) by each dimension and the loadings (which MCA labels as discrimination) of each variable for each dimension will be reported. The models presented had absolute convergence and the dimensions were extracted by the 'variable principal' method. For the MCA analysis, only whether contact frequency relates to financial investment will be looked into, and not whether or not change in contact relates to financial investment.

Results

Tables 1 and 2 show the raw frequencies of the responses. Table 3 shows the descriptive statistics for the control variables. It is important to stress here that the marital status relates to the legal marital status, not the relationship status with the cohabiting partner. Thus, being divorced or legally divorced does not imply that the mother is divorced or separated from the cohabiting father of the cohort member, rather that she had a previous marriage. Subsequently, difference scores for contact frequencies according to the four grandparent types were calculated.

Contact frequencies

Figure 1 shows that there are significant differences between all contrasts between grandparents. There was a significant difference between maternal and paternal grandmothers in face-to-face contact with their grandchild (mean difference: 0·455; $t(7467)=16{\cdot}9$; $p<0{\cdot}0001$; Cohen's $D=0{\cdot}2$; Fig. 1). Maternal grandfathers also had significantly more contact than paternal grandfathers (mean difference: 0·106; $t(7467)=3{\cdot}34$; $p=0{\cdot}0008$; Cohen's $D=0{\cdot}04$; Fig. 1). Maternal grandmothers had significantly more contact than paternal grandfathers (mean difference: 0·8; $t(7466)=26{\cdot}91$; $p<0{\cdot}0001$; Cohen's $D=0{\cdot}31$; Fig. 1). Maternal grandfathers, however, had significantly less contact than paternal grandmothers (mean difference: $-0{\cdot}23$; $t(7467)=-7{\cdot}81$; $p<0{\cdot}0001$; Cohen's $D=-0{\cdot}09$; Fig. 1). Within each lineage the effect of sex was also significant: maternal grandmothers had significantly more contact than maternal grandfathers (mean difference: 0·685; $t(7466)=34{\cdot}37$; $p<0{\cdot}0001$;

Table 1. Raw frequencies for contact frequency and change in contact frequency by grandparent category

	MGM	MGF	PGM	PGF
Contact frequency				
Every day/resident (1)	1916	1166	956	918
3–6 times a week (2)	1550	1213	1080	954
Once or twice a week (3)	1684	1796	2453	2101
Less often but at least once a month (4)	827	1015	1263	1233
Once every few months (5)	833	1019	961	1006
Once a year (6)	140	253	231	313
Less than once a year (7)	338	401	336	430
Never (8)	179	605	189	514
Change in contact frequency				
More often	2220	1752	1710	1357
About the same as before	4451	4975	4880	5315
Less often	798	742	879	797

MGM: Maternal Grandmother; MGF: Maternal Grandfather; PGM: Paternal Grandmother; PGF: Paternal Grandfather.

Table 2. Raw frequencies for financial benefits provided by lineage

		Maternal	Paternal
Diversity of benefits provided	0	1341	1537
	1	3768	3735
	2	1564	1438
	3	528	539
	4	249	194
	5	19	26
Essentials	No	5599	5803
	Yes	1870	1666
Household costs	No	6966	6972
	Yes	503	497
Gifts and extras for the baby	No	1743	2040
	Yes	5726	5429
Loans	No	6180	6140
	Yes	1289	1329
Money for childcare	No	7414	7415
	Yes	55	54

Cohen's $D=0{\cdot}4$; Fig. 1) and paternal grandmothers had significantly more contact than paternal grandfathers (mean difference: 0·336; $t(7468)=19{\cdot}04$; $p<0{\cdot}0001$; Cohen's $D=0{\cdot}22$; Fig. 1).

Table 3. Descriptive statistics (frequencies or mean and standard deviation) for control variables

		Mother	Father
Educational attainment	Higher degree	298	410
	First degree	1160	1073
	Diplomas in higher education	763	662
	A/AS/S levels	807	592
	O level/GCSE grades A–C	2591	2425
	GCSE grades D–G	745	836
	Other academic qualifications (incl. overseas)	184	170
	None of these qualifications	916	1290
	Missing	5	11
Age	Mean	29·56	31·73
	SD	5·29	5·45
Marital status of mother	Legally separated	116	
	Married, 1st and only marriage	4829	
	Remarried, 2nd or later marriage	327	
	Single, never married	1973	
	Divorced	221	
	Widowed	3	
Age of infant (months)	Mean	9·19	
	SD	0·5	

There are thus consistent differences in contact frequency according to lineage and sex of the grandparent. The largest differences are between maternal grandmothers and paternal grandfathers. Interestingly, paternal grandmothers had more frequent contact than maternal grandfathers. The effect of sex differences within the same lineage also appear to be larger than lineage differences within the same sex. Next, all the comparisons between grandparent categories were analysed in more detail (Table 4).

The effects from Table 4 will now be described briefly (parameter estimates shown in Appendix Table A1). In general, if the respondent was older then their mother would have relatively more contact than the respondent's partner's mother. If the parent was more highly educated instead of less highly educated, then their parent would have relatively more contact than the parent of their partner. With rising educational attainment of the parent, the difference between their father and their mother also becomes smaller. If the mother was not married instead of married, then grandmothers would become relatively more involved. If the infant was older, by contrast, then the maternal grandmother tended to have relatively more contact with the grandchild than the paternal grandfather.

While across models, the control variables predict differences in contact frequency, in none of the models do the control variables fully explain the observed differences between grandparent types. The main conclusion from the analyses is that the observed differences from Fig. 1 cannot be explained by the control variables (maternal educational attainment, paternal educational attainment, marital status of

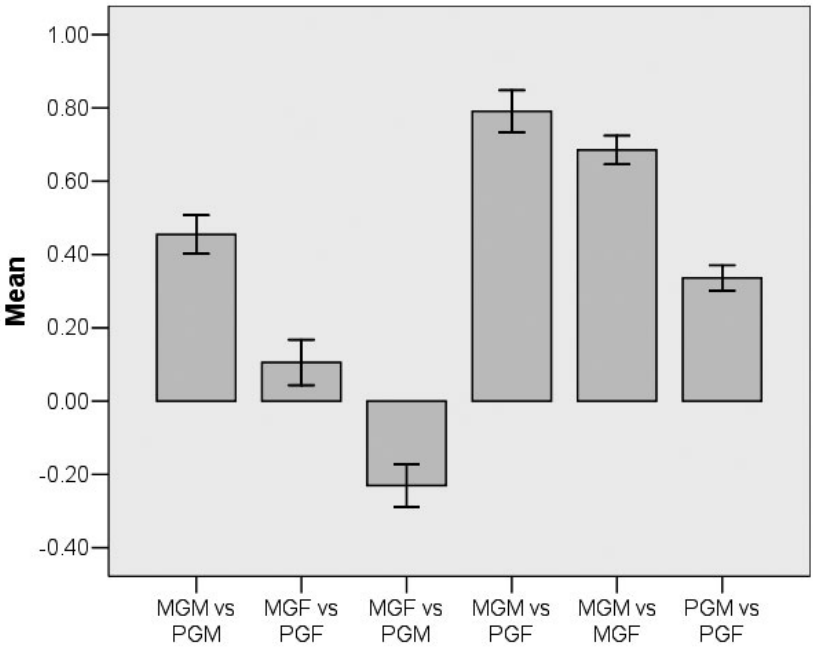

Fig. 1. Mean difference (first minus second listed) in contact frequency. A score of 0 represents no difference between the first and second grandparent listed; a score of 1 would indicate a difference between the first and second grandparent listed by one category from Table 1. Bars represent 95% confidence intervals. MGM: Maternal Grandmother; PGM: Paternal Grandmother; MGF: Maternal Grandfather; PGF: Paternal Grandfather.

Table 4. Summary of linear mixed models for difference scores in contact frequency (first minus second listed) with closest fit

Contact frequency	MGM vs PGM	MGF vs PGF	MGM vs PGF	MGF vs PGM	MGM vs MGF	PGM vs PGF
Maternal education	***	***	***	***	**	ns
Paternal education	***	***	***	***	**	***
Maternal age	*	***	ns	***	***	ns
Paternal age	ns	ns	ns	ns	ns	**
Maternal marital status	ns	ns	***	ns	ns	**
Age of the infant	ns	ns	ns	ns	*	ns
Estimated residual (± SE)	5·15 (± 0·08)	7·17 (± 0·11)	6·15 (± 0·1)	6·18 (± 0·1)	2·9 (± 0·05)	2·29 (± 0·04)

*Significant at $p<0{\cdot}05$; **significant at $p<0{\cdot}01$; ***significant at $p<0{\cdot}001$ (F tests).
The last row gives the estimated (unstandardized) residuals.
All residuals were significantly different from zero (all Wald Z test; $p<0{\cdot}0001$).

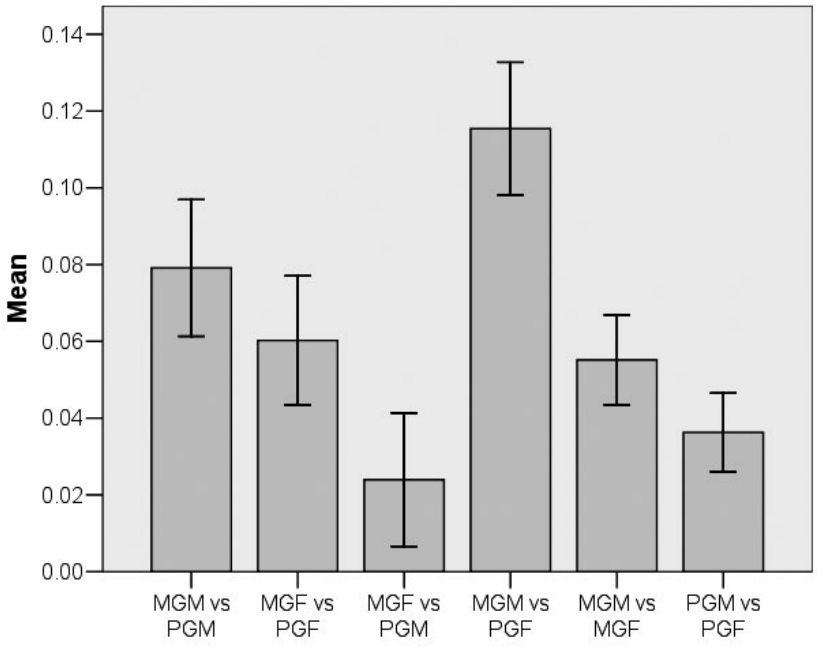

Fig. 2. Mean difference (first minus second listed) in contact change after birth of the grandchild. A score of 0 represents no difference between the first and second grandparent listed; a score of 1 would indicate a difference between the first and second grandparent listed by one category from Table 1. Bars represent 95% confidence intervals. MGM: Maternal Grandmother; PGM: Paternal Grandmother; MGF: Maternal Grandfather; PGF: Paternal Grandfather.

the mother and age of father, mother and the infant). There are thus significant differences between lineages in face-to-face contact frequency with the grandchild. Within each lineage, sex also influences face-to-face contact frequency, with grandmothers having significantly more contact with their grandchildren than grandfathers.

Changes in contact frequency since birth of grandchild

Figure 2 shows differences between grandparents in contact after their grandchild is born. There are consistent differences according to lineage with maternal grandparents having relatively more contact than paternal grandparents after the child was born. Within each lineage, grandmothers were also likely to have more contact than grandfathers after the child was born. Unlike the results from Fig. 1, maternal grandfathers have a greater increase in contact after the birth of a grandchild than paternal grandmothers. Also, unlike for raw contact frequencies (Fig. 1), the effects of lineage and sex appear to be of similar importance for changes in contact frequency following the birth of a grandchild. All differences shown in Fig. 2 are significantly different from zero (all t tests; $p<0{\cdot}0001$). The largest effect sizes were found for the comparisons between maternal grandmothers and paternal

Table 5. Summary of linear mixed models for difference scores in change of contact frequency (first minus second listed) with closest fit

Change in contact frequency	MGM vs PGM	MGF vs PGF	MGM vs PGF	MGF vs PGM	MGM vs MGF	PGM vs PGF
Maternal education	***	***	***	***	ns	***
Paternal education	ns	ns	ns	ns	ns	ns
Maternal age	ns	ns	ns	ns	ns	ns
Paternal age	ns	ns	ns	ns	ns	ns
Maternal marital status	ns	ns	ns	ns	ns	ns
Age of the infant	ns	ns	ns	ns	ns	ns
Estimated residual (± SE)	0·61 (± 0·01)	0·55 (± 0·01)	0·58 (± 0·01)	0·58 (± 0·01)	n/a	0·2 (± 0·003)

*Significant at $p<0·05$; **significant at $p<0·01$; ***significant at $p<0·001$ (F tests).
The last row gives the estimated (unstandardized) residuals.
All residuals were significantly different from zero (all Wald Z test; $p<0·0001$).

grandmothers, between maternal grandmothers and paternal grandfathers and between maternal grandmothers and maternal grandfathers (all Cohen's $D=0·1$). There were also sizeable differences between maternal grandfathers and paternal grandfathers and between paternal grandmothers and paternal grandfathers (both Cohen's $D=0·08$). The difference between maternal grandfathers and paternal grandmothers was small (Cohens's $D=0·03$).

Next, linear mixed models were constructed, as were done for contact frequency. These analyses are summarized in Table 5 and show that none of the control variables explained the observed differences from Fig. 2. The direction of the effects for the control variables was the same as described for Table 4 (parameter estimates can be found in Appendix Table A2), but only maternal education proved to be a significant predictor across all models. All residuals from the analyses were significantly different from zero in the Wald Z tests ($p<0·0001$). As above, it can thus be concluded that there are significant differences between maternal and paternal grandparents in contact frequency after birth. Also, within each lineage, grandmothers tended to have a greater increase in contact after the birth of a grandchild than grandfathers.

Financial investment

Figure 3 shows significant differences between maternal grandparents and paternal grandparents in the diversity of benefits provided, the provision of essentials and giving of gifts and extras for the baby. Maternal grandparents provided a wider range of financial benefits than paternal grandparents (mean difference=0·06; $t(7468)=4·27$; $p<0·0001$; Cohen's $D=0·049$). Similarly, maternal grandparents were more inclined to provide essentials for the baby than paternal grandparents (mean difference=0·03; $t(7468)=4·43$; $p<0·0001$; Cohen's $D=0·05$) as well as gifts (mean difference=0·04; $t(7468)=6·41$; $p<0·0001$; Cohen's $D=0·07$). Lineage does not appear to influence the

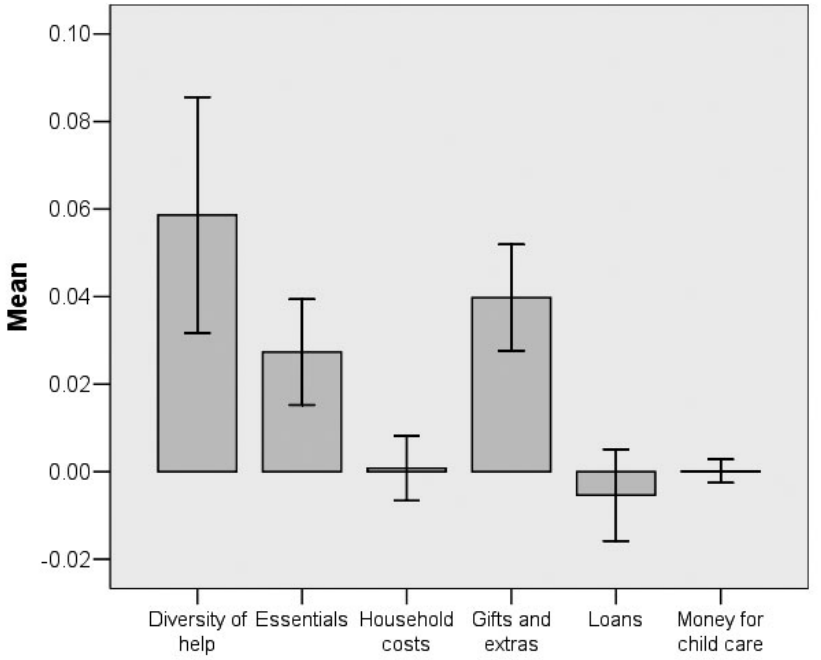

Fig. 3. Difference between maternal and paternal grandparents in help. A score of 0 represents no difference between the maternal and paternal grandparents listed. Positive scores indicate that maternal grandparents invest more than paternal grandparents; a score of 1 would indicate a difference between the first and second grandparent listed by one category from Table 2. Bars represent 95% confidence intervals.

provision of money for household costs, lending money or providing money for childcare (respectively: mean difference=0·001; $t(7468)=0{\cdot}21$; $p=0{\cdot}832$; mean difference= − 0·005; $t(7468)=-1$; $p=0{\cdot}32$; mean difference=0·1; $t(7468)=0{\cdot}1$; $p=0{\cdot}92$).

The differences shown for maternal and paternal grandparents in the diversity of financial benefits they provide, the provision of essentials and whether or not they gave gifts and extras for the baby in Fig. 3 cannot be attributed to the control variables (Table 6). Parameter estimates for the control variables can be found in Appendix Table A3.

Relationship between contact frequencies and grandparental investment

Subsequently multiple correspondence analysis (MCA) was performed with the (raw) contact frequency measures (contact with mother and contact with father) and the (raw) financial investment measures.

Maternal contact with mother and father and financial investment in grandchildren. Help with childcare was excluded as it did not discriminate at all in any of the analyses

Table 6. Summary of linear mixed models for difference scores in investment (maternal grandparents minus paternal grandparents) with closest fit

Investment	Diversity of help	Essentials	Gifts and extras
Maternal education	***	**	**
Paternal education	***	***	***
Maternal age	ns	*	ns
Paternal age	***	ns	*
Maternal marital status	*	ns	ns
Age of the infant	ns	ns	ns
Estimated residual (± SE)	1·4 (± 0·02)	0·28 (± 0·005)	0·29 ± 0·005)

*Significant at $p<0·05$; **significant at $p<0·01$; ***significant at $p<0·001$ (F tests).
The last row gives the estimated (unstandardized) residuals.
All residuals were significantly different from zero (all Wald Z test; $p<0·0001$).

Table 7. Loadings from multiple correspondence analysis on the maternal side

	Dimension	
	1	2
Contact with mother	0·31	0·83
Contact with father	0·25	0·83
Diversity	0·74	0·01
Essentials	0·54	0·01
Household costs	0·26	0·02
Gifts and extras	0·17	0·05
Loans	0·38	0·02
Eigenvalue	2·87	2·04
% of inertia	37·99	25·24

(all loadings <0·05). Multiple correspondence analysis showed that three dimensions had an eigenvalue larger than one. The third dimension was similar to the second dimension, loading predominantly on face-to-face contact with mother and face-to-face contact with father and smaller cross-loadings. Given that this factor does not appear to be substantially different and reaches the eigenvalue larger than one by several small crossloadings. Two dimensions were therefore extracted. These two dimensions account for 63% of the inertia (Table 7). The first dimension loads on nearly all items, albeit weakly for gifts and extras (0·17). This first dimension explains most inertia and therefore it is not possible to conclude that contact frequencies can indeed be grouped

Table 8. Correlations after transformation according to the first dimension for the maternal side

	Diversity	Essentials	Household costs	Gifts and extras	Loans	Contact with mother	Contact with father
Diversity	1·00	0·77	0·37	0·31	0·56	0·21	0·16
Essentials	0·77	1·00	0·31	0·17	0·27	0·18	0·13
Household costs	0·37	0·31	1·00	0·06	0·31	0·10	0·07
Gifts and extras	0·31	0·17	0·06	1·00	0·07	0·23	0·16
Loans	0·56	0·27	0·31	0·07	1·00	0·17	0·12
Contact with mother	0·21	0·18	0·10	0·23	0·17	1·00	0·73
Contact with father	0·16	0·13	0·07	0·16	0·12	0·73	1·00

together with various forms of 'financial investment'. The second dimension uniquely and strongly loads on contact with mother and contact with father and can thus be labelled 'contact frequency' (both loadings 0·8). As with factor analysis, one can examine the relationships after transformation (rotation) according to the extracted dimension(s). Transformation according to the first dimension showed that all variables correlate from weakly (0·06 to 0·1) to strongly (0·77) (Table 8).

Paternal contact with mother and father and financial investment in grandchildren. Help with childcare was excluded as it did not discriminate at all in any of the analyses (all loadings <0·05). Like the previous analysis, MCA showed that three dimensions fulfilled the 'eigenvalue above one' criterion. Again, like the previous analysis, the third dimension was essentially the same as the second dimension, only loading weaker. It was thus excluded and the analysis was re-done with two dimensions. These two dimensions account for 70% of the inertia (Table 9). The first dimension loads moderately (around 0·3) on nearly all items and strongly on the diversity of financial help provided. The correlations after transformation according to the first dimension are presented in Table 10. After transformation all variables correlate weakly (0·07 to 0·1) to strongly (0·7). The second dimension most strongly loads on the father's contact with his mother and father, the diversity of the financial benefits and gifts and extras. The first dimension explains most inertia and therefore it can be concluded that contact frequencies can be grouped together with various forms of 'financial investment'. The second dimension reveals that contact with mother and father is linked with the diversity of benefits provided as well as giving gifts and extras. The dimensions are very similar to those found for maternal contact with parents and financial investment, although the second dimension for this analysis does not uniquely load on contact with mother and father.

Discussion

The results show consistent differences in contact frequency by lineage. Moreover, within each lineage grandmothers had more frequent contact with their grandchild

Table 9. Loadings from multiple correspondence analysis on the paternal side.

	Dimension	
	1	2
Contact with mother	0·36	0·53
Contact with father	0·30	0·50
Diversity	0·85	0·49
Essentials	0·46	0·03
Household costs	0·32	0·14
Gifts and extras	0·25	0·32
Loans	0·32	0·03
Eigenvalue	2·87	2·04
% of inertia	41·05	29·12

Table 10. Correlations after transformation according to the first dimension for the paternal side

	Diversity	Essentials	Household costs	Gifts and extras	Loans	Contact with mother	Contact with father
Diversity	1·00	0·70	0·54	0·58	0·61	0·30	0·24
Essentials	0·70	1·00	0·30	0·17	0·24	0·23	0·18
Household costs	0·54	0·30	1·00	0·07	0·23	0·18	0·16
Gifts and extras	0·58	0·17	0·07	1·00	0·08	0·20	0·15
Loans	0·61	0·24	0·23	0·08	1·00	0·16	0·12
Contact with mother	0·30	0·23	0·18	0·20	0·16	1·00	0·75
Contact with father	0·24	0·18	0·16	0·16	0·12	0·75	1·00

than grandfathers. Paternal grandmothers were also significantly more likely to have frequent contact than maternal grandfathers. This effect is unlike previous studies, which have tended to find the reverse, namely that maternal grandfather's solicitude exceeds that of paternal grandmothers. It is unclear what could explain the difference between this study and other studies.

For all comparisons, the observed differences from Fig. 1 could not be (entirely) explained by the proposed control variables. While there thus were significant differences according to lineage in contact frequency, the effect sizes as measured by Cohen's *D* indicate that the influence of lineage is relatively weak. The sex differences within a lineage in contact frequencies also appear larger than lineage differences within a sex. Thus, while significant, the effect of lineage is generally not very strong, especially in comparison to the effect of sex.

Lineage also influenced change in contact with a parent following the birth of the grandchild. Maternal grandparents were relatively more inclined than paternal grandparents to have more frequent contact following the birth of a grandchild. Sex of the grandparent also influenced changes in contact frequency following a grandchild's birth: grandmothers were more inclined than grandfathers to see their child more frequently following the birth of their grandchild. For change in contact frequency with a parent following the birth, the size of sex differences between grandparents (within lineage) was similar to the size of differences between grandparents according to lineage (within the same sex). Unlike raw contact frequencies, maternal grandfathers were more inclined than paternal grandmothers to have more frequent contact with their child, after the birth of their grandchild.

Maternal grandparents provided their children with a wider range of financial support than paternal grandparents. Maternal grandparents also differed significantly from paternal grandparents in the likelihood of providing essentials and gifts and extras. Maternal grandparents were not significantly more likely than paternal grandparents to provide financial help towards childcare, household costs or loans. From Table 2 it is, however, evident that these forms of financial help, especially money for childcare and money for household costs, are less common than other forms of financial help, such as providing gifts and extras for the baby.

From the multiple correspondence analysis, it is clear that contact frequencies are indeed a useful proxy for financial investment. For both maternal and paternal grandparents, contact frequencies are positively related to measures of financial investment. For both analyses, maternal and paternal, there is an underlying distinct dimension to which both contact frequencies with mother and father relate. This dimension can be labelled 'general investment'. It was the first extracted dimension and explained the most variance, in both cases. Thus, rather than providing financial benefits forming an autonomous dimension, the provision of financial benefits appears to be consistently linked with frequent face-to-face contact. It must be noted, however, that these relationships between contact frequencies and this underlying dimension of investment are not very strong, only moderate (loadings of 0·25 to 0·36). As can be easily seen from Table 2, however, certain forms of financial investment – help with household costs for example – are not frequent at all. The relatively low occurrence of these forms of investment explains why the loadings as well as correlations after transformation can be low.

There are a number of limitations to the study. For example, the observed lineage differences in contact frequency could be explained in terms of distance: that is, if maternal grandparents live closer to their grandchildren than paternal grandparents do. However, Pollet *et al*. (2007) showed that there was no significant difference in how far maternal grandparents and paternal grandparents lived from their grandchild in a Dutch sample. In addition, they found that maternal grandparents, especially the maternal grandmother, generally travelled further than paternal grandparents in order to see their grandchild. Another limitation is that there are no controls for grandparental age or educational attainment. However, the analysis did have proxies for these, as grandparental age and education should correlate with parental age and education and these were included as controls. Moreover, the study sample is very large and the differences in investment and contact frequency according to lineage appear to

be a robust finding (most of the analyses $p<0{\cdot}0001$). These observed lineage differences in investment cannot be easily explained away (entirely) by an underlying third variable. A further limitation is that the dependent measures for financial investment are 'yes or no' measures: they do not give a quantifiable amount. In theory it is thus possible that while overall maternal grandparents are more inclined to provide a wider range of financial benefits than paternal grandparents, the amount invested is still larger. Further research is necessary to determine whether this is the case or not. At face value, however, it appears to be the case that maternal grandparents invest significantly more, given that they help in more ways, than paternal grandparents.

Future research can establish whether these differences in grandparental investment by lineage actually have any measurable effect on grandchildren's health and development. Data from historical populations and traditional populations suggest that this is the case: maternal grandmothers appear to have a beneficial effect on child health status and mortality (for example: Sear *et al.*, 2000, 2002; Voland & Beise, 2002). As the Millennium Cohort Study has a longitudinal design, we aim to investigate whether these lineage differences persist throughout the life course and have any measurable effect on the grandchild. Moreover, we aim to investigate whether there is a critical period in which these occur. It is expected that help from maternal grandparents has a larger impact when it occurs earlier in the child's life. For now, the more limited fact that maternal grandparents have more contact with their grandchildren as well as being more inclined to provide certain financial benefits for them than paternal grandparents, all else being equal, has been established.

Acknowledgments

The authors thank two anonymous referees for their useful comments, which greatly helped to improve an earlier draft. They would also like to thank the Centre for Longitudinal Studies (Institute of Education, University of London) and the ESRC Data Archive for access to the Millennium Cohort Study (MCS). The MCS is funded by the ESRC and a consortium of government departments led by the Office of National Statistics. Research at the Institute of Child Health and Great Ormond Street Hospital for Children NHS Trust benefits from R&D funding received from the NHS Executive.

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Appendix

Table A1. Standardized parameter estimates in linear mixed models for difference scores in contact frequency (left column: first minus second)

			β	*p*
MGM vs PGM	Maternal education	Higher degree	0·141	0·051
		First degree	0·225	<0·0001
		Diplomas in higher education	0·309	<0·0001
		A/AS/S levels	0·291	<0·0001
		O level/GCSE grades A–C	0·370	<0·0001
		GCSE grades D–G	0·381	<0·0001
		Other academic qualifications	− 0·743	<0·0001
		None of these qualifications	0	
	Paternal education	Higher degree	− 0·142	0·023
		First degree	− 0·135	0·003
		Diplomas in higher education	− 0·156	0·001
		A/AS/S levels	− 0·142	0·005
		O level/GCSE grades A–C	− 0·189	<0·0001
		GCSE grades D-G	− 0·167	<0·0001
		Other academic qualifications	0·631	<0·0001
		None of these qualifications	0	
	Maternal age (years)		0·026	0·037

Table A1. *Continued*

			β	p
MGF vs PGF	Maternal education	Higher degree	0·168	0·021
		First degree	0·242	<0·0001
		Diplomas in higher education	0·308	<0·0001
		A/AS/S levels	0·303	<0·0001
		O level/GCSE grades A–C	0·337	<0·0001
		GCSE grades D–G	0·309	<0·0001
		Other academic qualifications	− 0·588	<0·0001
		None of these qualifications	0	
	Paternal education	Higher degree	− 0·106	0·090
		First degree	− 0·160	0·001
		Diplomas in higher education	− 0·193	<0·0001
		A/AS/S levels	− 0·169	0·001
		O level/GCSE grades A–C	− 0·242	<0·0001
		GCSE grades D–G	− 0·196	<0·0001
		Other academic qualifications	0·505	<0·0001
		None of these qualifications	0	
	Maternal age (years)		0·045	<0·0001
MGM vs PGF	Maternal education	Higher degree	0·114	0·111
		First degree	0·169	0·001
		Diplomas in higher education	0·254	<0·0001
		A/AS/S levels	0·246	<0·0001
		O level/GCSE grades A–C	0·316	<0·0001
		GCSE grades D–G	0·312	<0·0001
		Other academic qualifications	− 0·774	<0·0001
		None of these qualifications	0	
	Paternal education	Higher degree	− 0·190	0·002
		First degree	− 0·188	<0·0001
		Diplomas in higher education	− 0·220	<0·0001
		A/AS/S levels	− 0·197	<0·0001
		O level/GCSE grades A–C	− 0·228	<0·0001
		GCSE grades D–G	− 0·171	<0·0001
		Other academic qualifications	0·463	<0·0001
		None of these qualifications	0	
	Marital status of mother	Legally separated	0·076	0·408
		Widowed	− 0·479	0·397
		Remarried	0·067	0·232
		Single, never married	0·124	<0·0001
		Divorced	0·132	0·050
		Married, 1st and only marriage	0	
MGF vs PGM	Maternal education	Higher degree	0·207	0·004
		First degree	0·310	<0·0001
		Diplomas in higher education	0·369	<0·0001
		A/AS/S levels	0·355	<0·0001
		O level/GCSE grades A–C	0·383	<0·0001
		GCSE grades D–G	0·359	<0·0001

Table A1. *Continued*

			β	p
MGF vs PGM		Other academic qualifications	−0·514	<0·0001
		None of these qualifications	0	
	Paternal education	Higher degree	−0·035	0·570
		First degree	−0·090	0·052
		Diplomas in higher education	−0·118	0·015
		A/AS/S levels	−0·104	0·039
		O level/GCSE grades A–C	−0·201	<0·0001
		GCSE grades D–G	−0·194	<0·0001
		Other academic qualifications	0·680	<0·0001
		None of these qualifications	0	
	Maternal age (years)		0·078	<0·0001
MGM vs MGF	Maternal education	Higher degree	−0·119	0·105
		First degree	−0·158	0·002
		Diplomas in higher education	−0·129	0·012
		A/AS/S levels	−0·135	0·007
		O level/GCSE grades A–C	−0·070	0·079
		GCSE grades D–G	−0·018	0·719
		Other academic qualifications	−0·246	0·002
		None of these qualifications	0	
	Paternal education	Higher degree	−0·140	0·026
		First degree	−0·051	0·275
		Diplomas in higher education	−0·036	0·461
		A/AS/S levels	−0·038	0·457
		O level/GCSE grades A–C	0·041	0·250
		GCSE grades D–G	0·059	0·184
		Other academic qualifications	−0·163	0·046
		None of these qualifications	0	
	Maternal age (years)		−0·082	<0·0001
	Infant's age (months)		0·026	0·024
PGM vs PGF	Paternal education	Higher degree	−0·148	0·010
		First degree	−0·156	<0·0001
		Diplomas in higher education	−0·160	0·001
		A/AS/S levels	−0·143	0·004
		O level/GCSE grades A–C	−0·110	0·001
		GCSE grades D–G	−0·046	0·304
		Other academic qualifications	−0·231	0·005
		None of these qualifications	0	
	Marital status of mother	Legally separated	0·122	0·192
		Widowed	0·209	0·716
		Remarried	0·036	0·532
		Single, never married	0·124	<0·0001
		Divorced	0·083	0·227
		Married, 1st and only marriage	0	
	Paternal age (years)		−0·041	0·001

p values for β are based on t tests.

Table A2. Standardized parameter estimates in linear mixed models for difference scores in change of contact frequency (left column: first minus second)

			β	p
MGM vs PGM	Maternal education	Higher degree	0·132	0·048
		First degree	0·139	0·002
		Diplomas in higher education	0·070	0·155
		A/AS/S levels	0·207	0·000
		O level/GCSE grades A–C	0·125	<0·0001
		GCSE grades D–G	0·090	0·067
		Other academic qualifications	− 0·171	0·034
		None of these qualifications	0	
MGF vs PGF	Maternal education	Higher degree	0·115	0·085
		First degree	0·096	0·031
		Diplomas in higher education	0·091	0·064
		A/AS/S levels	0·190	<0·0001
		O level/GCSE grades A–C	0·114	0·003
		GCSE grades D–G	0·033	0·501
		Other academic qualifications	− 0·171	0·035
		None of these qualifications	0	
MGM vs PGF	Maternal education	Higher degree	0·205	0·002
		First degree	0·190	<0·0001
		Diplomas in higher education	0·154	0·002
		A/AS/S levels	0·204	<0·0001
		O level/GCSE grades A–C	0·145	<0·0001
		GCSE grades D–G	0·053	0·281
		Other academic qualifications	− 0·125	0·123
		None of these qualifications	0	
MGF vs PGM	Maternal education	Higher degree	0·042	0·531
		First degree	0·045	0·305
		Diplomas in higher education	0·006	0·909
		A/AS/S levels	0·192	<0·0001
		O level/GCSE grades A–C	0·094	0·014
		GCSE grades D–G	0·072	0·146
		Other academic qualifications	− 0·216	0·007
		None of these qualifications	0	
PGM vs PGF	Maternal education	Higher degree	0·118	0·078
		First degree	0·080	0·072
		Diplomas in higher education	0·140	0·004
		A/AS/S levels	− 0·013	0·783
		O level/GCSE grades A–C	0·027	0·479
		GCSE grades D–G	− 0·067	0·174
		Other academic qualifications	0·087	0·284
		None of these qualifications	0	

p values for β are based on t tests.

Table A3. Standardized parameter estimates in linear mixed models for difference scores in financial investment (left column: maternal minus paternal)

			β	p
Diversity index (maternal–paternal)	Maternal education	Higher degree	0·218	0·003
		First degree	0·187	<0·0001
		Diplomas in higher education	0·240	<0·0001
		A/AS/S levels	0·199	<0·0001
		O level/GCSE grades A–C	0·178	<0·0001
		GCSE grades D–G	0·167	<0·0001
		Other academic qualifications	− 0·167	0·041
		None of these qualifications	0	
	Paternal education	Higher degree	− 0·298	<0·0001
		First degree	− 0·258	<0·0001
		Diplomas in higher education	− 0·263	<0·0001
		A/AS/S levels	− 0·257	<0·0001
		O level/GCSE grades A–C	− 0·187	<0·0001
		GCSE grades D–G	− 0·186	<0·0001
		Other academic qualifications	0·117	0·156
		None of these qualifications	0	
	Marital status of mother	Legally separated	0·028	0·766
		Widowed	− 0·866	0·132
		Remarried	0·075	0·191
		Single, never married	0·070	0·015
		Divorced	− 0·072	0·295
		Married, 1st and only marriage	0	
	Paternal age (years)		0·044	0·001
Essentials (maternal–paternal)	Maternal education	Higher degree	0·071	0·333
		First degree	0·118	0·020
		Diplomas in higher education	0·182	0·0004
		A/AS/S levels	0·108	0·033
		O level/GCSE grades A–C	0·082	0·039
		GCSE grades D–G	0·076	0·128
		Other academic qualifications	− 0·145	0·076
		None of these qualifications	0	
	Paternal education	Higher degree	− 0·179	0·005
		First degree	− 0·205	<0·0001
		Diplomas in higher education	− 0·204	<0·0001
		A/AS/S levels	− 0·122	0·018
		O level/GCSE grades A–C	− 0·115	0·001
		GCSE grades D–G	− 0·117	0·010
		Other academic qualifications	0·093	0·259
		None of these qualifications	0	
	Maternal age (years)		0·032	0·011

Table A3. *Continued*

			β	p
Gifts and extras (maternal–paternal)	Maternal education	Higher degree	0·188	0·010
		First degree	0·185	0·0002
		Diplomas in higher education	0·185	0·0003
		A/AS/S levels	0·209	<0·0001
		O level/GCSE grades A–C	0·190	<0·0001
		GCSE grades D–G	0·150	0·003
		Other academic qualifications	0·014	0·864
		None of these qualifications	0	
	Paternal education	Higher degree	− 0·262	0·000
		First degree	− 0·168	0·0003
		Diplomas in higher education	− 0·157	0·002
		A/AS/S levels	− 0·215	<0·0001
		O level/GCSE grades A–C	− 0·157	<0·0001
		GCSE grades D–G	− 0·105	0·020
		Other academic qualifications	0·034	0·681
		None of these qualifications	0	
	Paternal age	(years)	0·030	0·014

p values for β are based on t tests.