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ORIGINAL PAPER

Birth order matters: the effect of family size and birth order on educational attainment

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Abstract Using the British Household Panel Survey, we investigate if family size and birth order affect children's subsequent educational attainment. Theory suggests a trade-off between child quantity and "quality" and that siblings are unlikely to receive equal shares of parental resources devoted to children's education. We construct a new birth order index that effectively purges family size from birth order and use this to test if siblings are assigned equal shares in the family's educational resources. We find that the shares are decreasing with birth order. Ceteris paribus, children from larger families have less education, and the family size effect does not vanish when we control for birth order. These findings are robust to numerous specification checks.

Keywords Family size · Birth order · Education

JEL Classification I2 · J1

1 Introduction

The promotion of educational attainment is an important priority of policy makers. The economics of the family suggests that children's educational achievement is related to

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family size and that there is a trade-off between child quantity and "quality" (Becker 1960; Becker and Lewis 1973) where child 'quality' is proxied by educational outcomes. A number of arguments also suggest that siblings are unlikely to receive equal shares of the resources devoted by parents to their children's education.

There are various hypotheses in the literature about the impact of birth order. Those predicting negative effects relate to greater parental time endowments for lower birth order children, greater devolvement of responsibility to lower birth order children and the simple fact that mothers are older when they have higher than lower birth order children. Those hypotheses predicting positive effects of birth order on education are: the growth of family income over the life cycle; the possibility that older siblings may be encouraged to leave school early to assist in providing resources for the younger members of the family; parental child-raising experience that might advantage younger siblings; and finally, the possibility that younger children may benefit from time inputs both from parents and older siblings.

A challenge in estimation of birth order and family size effects is that birth order relates to family size. The first born in any family always has a higher probability of being in a small family than those children born later in the birth order. Studies estimating separate birth order and family size effects typically include dummy variables for birth order and a separate continuous variable for family size. But this does not appropriately purge the family size effect from the birth order effect. In this paper, we put forward a simple specification of a *birth order index* that is orthogonal to family size and which we utilise in our estimation. An additional advantage of this method is its parsimony.

We use unique retrospective family background data from wave 13 of the British Household Panel Survey to explore the degree to which family size and birth order affect a child's subsequent educational attainment. We construct a test of whether or not siblings are assigned equal shares in the family's educational resources. We show that they are not and that the shares are decreasing with birth order. Controlling for parental family income, parental age at birth and family level attributes, we find that children from larger families have lower educational attainment. In addition, there is a separate negative birth order effect. Our findings are robust to a number of specification checks. In contrast to Black et al. (2005), the family size effect does not vanish once we control for birth order.

There have been many studies estimating the impact of family composition of educational attainment. These typically do not convincingly disentangle birth order from family size effects, as noted by Hanushek (1992), although Ejrnaes and Portner (2004) employ a measure of relative birth order to try to overcome this problem.[1] More recently, an important study by Black et al. (2005) used data for the entire Norwegian population to estimate the impact of family size and birth order on education, employing dummy variables for birth order. They found that their negative correlation between family size and children's educational attainment became negligible once they included dummy variable indicators for birth order. This finding was robust to the use of twin births as an instrument for family size (twins being an exogenous variation in family size) and to estimating birth order

[1] Their measure of relative birth order is $[(\phi - 1)/(N - 1)]$, where ϕ is birth order and N the number of children in the family.

effects separately by family size. There is, to our knowledge, only one similar study for Britain. Iacovou (2001) used the National Child Development Study, a longitudinal study of all children born in the first week of March 1958, to estimate the impact of family composition on educational attainment up to age 23. She finds a statistically significant negative correlation between educational attainment on the one hand and higher birth order and larger family size on the other. She disentangles birth order effects from family size to a considerable degree by using dummy variables picking up a variety of family patterns.[2] We build on this approach by constructing a composite birth order index that effectively purges family size from birth order and which allows parsimonious estimation of birth order effects.

Our paper is set out as follows. In Section 2, we summarize the main hypotheses about the impact of family size and birth order on children's education. Section 3 describes the data and explanatory variables, while an appendix provides details of the British educational system. Section 4 outlines the test and presents the main estimates. Section 5 discusses the results of a number of robustness checks. These include using years of schooling rather than level of educational attainment as the dependent variable, allowing for potential endogeneity of family size (as suggested inter alia by Cigno and Ermisch 1989 and Barmby and Cigno 1990), experimenting with interactions by gender, by ethnicity, by whether or not the respondent grew up in a household with both biological parents and by working mother. Our results are robust to all these checks, as will be demonstrated. The final section concludes.

2 Background

There are a number of hypotheses suggesting that family size and birth order might affect educational investments, even apart from income effects. For a given level of parental income, family size is likely to reduce the per capita resources that can be spent on educational investments. But the shares of family resources that each child will receive are likely to differ across birth order for a number of reasons. First, given that parents have a fixed time endowment, the first born will receive a greater time endowment than subsequent children who have to compete for parental attention. To the extent that greater parental time inputs translate into higher educational achievement, first born children may fare better than subsequent children. However, this argument also serves to emphasise the role of gaps between children; if children are widely spaced, then the last born child might benefit more as older children leave the family nest or through the expansion of time inputs as both parents and older siblings spend time with the last born child (Behrman and Taubman 1986; Birdsall 1991; Hanushek 1992).

Life cycle effects can also matter. If parents are young at first birth, they may also be poorer than they will be later in the life cycle, and hence, resources might be lower for first-born children of young—and possibly immature—parents. Hence,

[2] Iacovou (2001) included dummy variables for the younger of two children, the middle of three children, the younger of three children, the middle of four children, the youngest of four children, the middle of five children, the youngest of five children, the middle of six or more children, and the youngest of six or more children.

younger siblings might benefit through the growth of family income over the life cycle (Parish and Willis 1993).

Other factors can also work in both directions. If older children are expected to assume more responsibility in assisting with younger siblings, this training may lead them to perform more responsibly at school and become higher achievers. On the other hand, older siblings may be encouraged to leave school early to assist in providing resources for the family, giving an advantage to later birth order siblings with respect to educational attainment.

Biological factors may also matter. By definition, mothers having higher birth order children are older than when they have lower birth order children. To the extent that older mothers have lower birth weight children and birth weight is correlated with ability and/or access to resources, then later children may fare worse.[3] But on the other hand, parents may learn with practice and experience, and hence, later children might be advantaged relative to earlier ones. Finally, cultural and legal factors may also play a part. If there is land or an estate to be passed on and inheritance customs favour the first born, parents may choose to invest more in the formal education of subsequent children to compensate.[4]

In summary, we would a priori expect family size to have a negative effect on educational attainment, as found in the bulk of the literature. A priori birth order might have a positive or a negative effect, depending on the degree to which the various influences outlined above affect children who are otherwise similar. Ultimately, it is an empirical question as to which dominates. We might also expect birth order effects on education to vary across countries depending on their stages of development, their patterns of birth spacing and fertility and their inheritance practices.[5] And our analysis does indeed suggest that British family size and birth order effects on education are different from those found in Norway by Black et al. (2005).[6]

3 The data and variables

Our data source is wave 13 of the British Household Panel Survey (BHPS), conducted in 2003–2004. The BHPS is a nationally representative random-sample

[3] There is clearly a need to disentangle birth order effects from parental cohort effects. Some mothers have their first born when they are teenagers, whereas others have their first birth in their late thirties. As we discuss later, these maternal age differences might translate into different inputs of time, energy and experience, which may affect children's educational attainment quite distinctly from birth order effects.

[4] Ejrnaes and Portner (2004) hypothesise that parental fertility choices induce a birth order effect quite separate from the above hypotheses, owing to an optimal stopping calculus based on heterogeneity in degrees of parental inequality aversion. Booth and Kee (2006) use the 2003 wave of the BHPS to investigate intergenerational patterns of fertility in women's origin and destination families, controlling for birth order.

[5] Capital market imperfections may affect family resources devoted to education. In Britain, primary and secondary schooling is paid for by the state, and a grants and loans system is in place for higher education (although not further education). British children are, thus, more likely to become independent from their parents, and their educational choices might be less constrained by parental resources and birth order than in developing countries without such a long-established system of subsidised education.

[6] Bjorklund et al. (2004) find, using administrative data, separate effects of birth order and family size on young adults' *earnings* in Norway, Finland and Sweden.

survey of private households in Britain. Although limited information on family background was collected in earlier waves, the questionnaire was expanded in the 13th wave to elicit additional information about family and parental background and the childhood home. Of particular interest are the new variables about sibling numbers and birth order. We use these to investigate the degree to which family size and birth order within the family affect an individual's subsequent educational attainment.[7] Other family background variables proxy family-level heterogeneity.

The major strength of the dataset for our purposes is that it provides rich information about parental characteristics and family background attributes as well as respondents' own highest educational attainment. However, there are also a number of limitations of the data. These include the lack of direct information about siblings (apart from their number) and the fact that we do not know whether or not there were twins in the family. Rosenzweig and Zhang (2006), for example, show that twins can be a valid instrument for family size if additional information such as birth weight is available. This avenue of investigation is not open to us. As we do not directly observe the respondents' siblings, it is impossible to control for sex composition within a family and potential correlation between unobservables and endogenous variables. We are also missing some information about family structure for which we would like to control. For example, we do not have information about the gaps between siblings nor do we have data on whether or not there were any stepchildren. This could matter, as parents might be more willing to invest in the education of their biological children rather than their stepchildren from other remarriages. Moreover, previous work by Black et al. (2005) suggested using fixed-effect analysis to account for the possible correlation between the unobservables and the explanatory variables. We cannot use this technique, as we do not observe the same individuals over time. Nonetheless, in spite of these limitations, our dataset provides other information that is unavailable in the vast majority of individual-level surveys, and this allows us to establish some interesting associations in our analysis.

3.1 Highest educational qualifications

The BHPS reports each individual's highest educational qualification and not years of education. The dependent variable for most of our analysis is an indicator comprising six ordered categories, ranging from highest educational level to the lowest. The proportions of our estimating subsample falling into each group are given in Table 1.[8] We also imputed average years of schooling for each highest

[7] These variables are retrospective, and with retrospective data, there are always issues about potential recall error. However, the variables in which we are interested relate to attributes that are unlikely to be forgotten; it is hard to imagine that anyone within our sample of interest, 28- to 55-year-olds, would be likely to forget the number of siblings or their own birth order.

[8] The highest educational attainment measure is ordered as follows: (1) No defined qualification; (2) Vocational or low-level academic qualification(s) (e.g. commercial or clerical qualifications, CSE grades 2–5, apprenticeship); (3) One or more Ordinary level or equivalent qualifications taken at age 16 at end of compulsory schooling (and forming the selection mechanism into Advanced-level courses); (4) One or more Advanced level qualifications (or equivalent) representing university entrance-level qualification typically taken at age 18; (5) Teaching, nursing or other higher qualifications (e.g. technical, professional qualifications); (6) University first or higher degree.

Table 1 Variable means and descriptions

Variable		Women	Men	Total
Name	Description	*n*=4,208	*n*=3,514	*N*=7,722
Age2833	Age cohort between 28 and 33 years old	0.206	0.207	0.207
Age3439	Age cohort between 34 and 39 years old	0.244	0.231	0.238
Age4045	Age cohort between 40 and 45 years old	0.230	0.231	0.230
Age4650	Age cohort between 46 and 50 years old	0.158	0.168	0.162
Age5155	Age cohort between 51 and 55 years old	0.163	0.163	0.163
female	Dummy=1 if respondent is female	0.545	0.455	
edu1	No defined qualification	0.146	0.131	0.136
edu2	Other qualification	0.080	0.061	0.071
edu3	O level	0.197	0.165	0.071
edu4	A level	0.111	0.121	0.182
edu5	Other higher qualification	0.301	0.338	0.116
edu6	Degree or above	0.166	0.184	0.317
edu_yr	Education in years	12.963	13.191	13.067
mum20	Mum <20 when respondent was born	0.081	0.094	0.087
mum2125	Mum between 21 and 25 when respondent was born	0.282	0.262	0.273
mum2630	Mum between 26 and 30 when respondent was born	0.272	0.271	0.272
mum3140	Mum between 31 and 40 when respondent was born	0.252	0.222	0.238
mum41up	Mum >41 when respondent was born	0.034	0.031	0.033
dad20	Dad <20 when respondent was born	0.025	0.034	0.029
dad2125	Dad between 21 and 25 when respondent was born	0.175	0.171	0.173
dad2630	Dad between 26 and 30 when respondent was born	0.281	0.279	0.280
dad3140	Dad between 31 and 40 when respondent was born	0.312	0.279	0.297
dad41up	Dad >41 when respondent was born	0.083	0.084	0.084
kidinner	Lived in inner city as child	0.096	0.108	0.101
kidsubu	Lived in a suburban area as child	0.227	0.224	0.226
kidtown	Lived in a town as a child	0.290	0.283	0.287
kidvilla	Lived in a village as a child	0.204	0.208	0.206
kidrural	Lived in a rural or country area as a child	0.132	0.129	0.131
kidmob	Moved around as a child	0.051	0.047	0.049
less_bk	*D*=1 if respondent had not many books during childhood	0.257	0.330	0.290
more_bk	*D*=1 if respondent had quite a few books during childhood	0.346	0.380	0.362
lots_bk	*D*=1 if respondent had lots of books during childhood	0.387	0.280	0.338
mum_deg	Mother has further ed qf, degree, or further qf	0.205	0.185	0.196
dad_deg	Father has further ed qf, degree, or further qf	0.353	0.332	0.343
workmum	Mother working when 14 years old	0.413	0.363	0.390
nonwhite	Ethnic group is non-white	0.029	0.027	0.028
famnorm	Living with both biological parents from birth till age 16	0.815	0.825	0.820
fam size	Number of children in respondent's own family, top coded at 10	3.503	3.371	3.443
firstborn	Dummy=1 if respondent is the eldest in the family	0.308	0.332	0.319
bo2	Birth order is second	0.295	0.302	0.298
bo3	Birth order is third	0.159	0.145	0.153
bo4	Birth order is fourth	0.073	0.059	0.067
bo5	Birth order is fifth	0.032	0.037	0.034
bo6	Birth order is sixth	0.022	0.018	0.020
bo7	Birth order is seventh	0.016	0.009	0.013
bo8	Birth order is eighth	0.007	0.006	0.007
bo9	Birth order is ninth	0.005	0.004	0.005
bo10	Birth order is tenth	0.005	0.005	0.005
onlychild	Dummy=1 if respondent is the only child in the family	0.078	0.082	0.080

educational qualification and use the log of this as the dependent variable when undertaking some robustness checks of our main results. Appendix A provides a brief summary of the British educational system. School is compulsory between the ages of 5 and 16 and is free. Schooling beyond that can continue for two more years in secondary schools or be more vocationally based in the further education sector, or can—beyond the age of 18—take place in universities.

3.2 Family size and birth order

Respondents in wave 13 were asked (question D108): “How many brothers and sisters have you ever had?”[9] This was immediately followed by the question: “So including yourself, there were (D108+1) children in your family?” We used this information to construct a variable for the total number of children in the family. The next question asked “Where were you born in relation to your brother(s) and sister(s), that is, were you the first, second, third or subsequent child?” There followed a list of up to 10 possibilities, with the 10th top-coded as “tenth (or later).”[10]

Table 2 cross-tabulates family size by birth order. For the moment, we combine first-born and only children into the one category, although later we disaggregate them. Each cell of Table 2 reports the birth order means for respondents in each family size. The second row shows that our sample comprises 2,341 respondents from two-child families, and approximately half of these are first born and half are last born. The third row shows that of those 1,940 respondents from three-child families, 35.9% are first born, 32.6% are second born, and 31.5% are last born. The table also reveals that for larger families in our sample, there are relatively few observations. Moreover, there are obviously a greater number of birth order categories within each of the larger family sizes; consequently, cell sizes for birth order are quite small in the larger families. For example, consider the 137 respondents from eight-child families shown in the eighth row of the table. The smallest cell size in this row is for the fifth born for whom we have just 12 observations (0.088×137). The largest cell size—for the seventh born—comprises 25 cases. For respondents from nine-child families, we have 96 observations, and the smallest cell size in this row is for the second born, representing 4.1% of individuals from nine-child families and comprising four cases. The largest cell size is for the sixth born, comprising 16 cases. The last row of the table gives the distribution of the 174 individuals from families of ten or more children across birth order. Here, the smallest cell size is for the third born (six cases).

The fact that cell sizes across birth order categories are relatively small for some of our larger families suggests that it is important to find a parsimonious way of representing the data. To this end, in Section 4.1, we convert responses to the birth

[9] All respondents were initially asked Question D107: “Have you ever had any brothers or sisters who lived in the same household as you as a child? DO NOT INCLUDE STEP OR FOSTER SIBLINGS.” For those who answered “yes” in D107, respondents were then asked question D108 and D108+1. Because of the construction of this question, we obtain the information only on natural siblings. Hence, we are unable to control for the effect of mixed families arising from remarriages.

[10] Unfortunately, the BHPS does not provide information about the age gaps between siblings.

Table 2 Distribution of birth order across family size (age 28–55)

Family size	Birth order										
	Eldest	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth	Ninth	≥Tenth	Number of observations
Only child	1.0										617
2-children	0.506	0.494									2,341
3-children	0.359	0.326	0.315								1,940
4-children	0.274	0.244	0.255	0.227							1,141
5-children	0.193	0.178	0.223	0.188	0.218						664
6-children	0.167	0.142	0.180	0.175	0.152	0.184					401
7-children	0.166	0.171	0.119	0.104	0.100	0.128	0.212				211
8-children	0.088	0.080	0.146	0.153	0.088	0.131	0.183	0.131			137
9-children	0.156	0.041	0.073	0.052	0.104	0.168	0.094	0.146	0.166		96
10+-children	0.063	0.051	0.035	0.075	0.098	0.126	0.115	0.121	0.115	0.201	174
Number of observations	3,094	2,302	1,180	5,15	266	157	99	53	36	35	7,722

Source: British Household Panel Study, wave 13 (row figures may not add to 1 owing to rounding)

order question into a new birth order index.[11] This index not only parsimoniously represents the data but also has the advantage of reducing almost to zero the correlation between family size and birth order.

3.3 Heterogeneity across families

As the wave 13 data are cross-sectional, albeit with a longitudinal element, we do not use panel techniques. But wave 13 of the BHPS does provide unique information about family attributes that allows us to control for family-specific heterogeneity. The presence of books in the parental home when the respondent was a child forms a proxy for family-specific attitudes to education. Households with many books are likely to have a more positive attitude to learning through the written word than are households with few or no books.[12] We proxy parental wealth by dummy variables, taking the value 1 if the mother had a university degree or a teaching, nursing or other higher qualifications, and 0 otherwise, and likewise for the father. We also use a dummy variable indicating whether or not the mother worked when the respondent was aged 14 as a proxy for available maternal time and parental wealth. Area-specific factors are captured by a set of variables indicating the type of area in which the family mostly lived when the respondent was a child.[13]

[11] Black et al. (2005) had the entire Norwegian population in their dataset and were therefore able to estimate the effects of birth order separately for each family size. We are unable to do this across all birth orders owing to very small cell sizes, as illustrated in Table 2. However, as reported later in this paper, we did experiment with this form of specification up to birth order of seven and above.

[12] Respondents were asked: “Thinking about the time from when you were a baby until the age of ten, which of the following statements best describes your family home: There were a lot of books in the house; There were quite a few books in the house; There were not very many books in the house; Don’t know.” We constructed dummy variables for “a lot of books in the house” and “quite a few books in the house”. The base in the regressions is “not many books in the house”.

[13] The precise question about area of residence was: “Please look at this card and tell me which best describes the type of area you *mostly* lived in from when you were a baby to 15 years.” Responses are described in Table 13 Appendix A. The base for the regressions is “lived in a suburban area”.

Section 2 summarised hypotheses advanced in the literature suggesting that parental age at first birth matters for children's educational attainment. Children born to younger parents—controlling for family income, family size and birth order—might have different educational opportunities. On the one hand, younger parents may be less patient, less experienced and less willing to give up career or social concerns to spend the time with children that might develop their learning potential. But on the other hand, younger parents might not only have higher birth weight children but also have more energy and a greater willingness to spend quality time with their children, time that might enhance their learning. The 13th wave of the BHPS asks about the age of each of the parents when the child was born. Thus, we are able to include age cohort dummies for each parent.

3.4 Estimating subsample

Our estimating subsample consists of 7,722 individuals (3,514 men and 4,208 women) aged between 28 and 55 years and with valid information on the three main variables (education, family size and birth order). We excluded from the sample individuals aged less than 28 to ensure that respondents had completed their education. We also dropped seven cases whose mothers were still potentially fertile at the interview date to ensure that birth order was complete from the mother's perspective.[14]

Table 1 gives the means of the variables used in our analysis, with a brief description of each. Thus, of our estimating sample, 20.7% are between the ages of 28 and 33, 23.8% are 34 to 39, 23% are 40 to 45, 16.2% are 46 to 50, and 16.3% are between 51 and 55 years old. The sample is 54.5% female, 16.6% has a degree or above, and the average number of years of education is around 13. The mean number of children is 3.44, and the standard deviation is 1.95. First-born children account for 31.9% of the sample, second born 29.8%, third born 15.3%, fourth born 6.7%, fifth born 3.4%, and the remainder are as shown in the table. Note that the first born comprise 1,166 men and 1,296 women, and thus, males outnumber females in this group.

Table 3 cross-tabulates the number of children (including the respondent) by the respondent's highest educational qualification, while Table 4 cross-tabulates the child's birth order by the respondent's highest educational qualification. The figures in parentheses in the tables give the column percentages. The mean family size (including the respondent) is 3.443, while median family size (including the respondent) is two children. The mean educational level is one or more O levels, while the median educational level is 'other higher qualification'.

The first column of Table 3 shows educational attainment in one-child families and reveals that just around 10% of children from one-child families had no qualification, 10% had Vocational or low-level academic qualification(s), 21% had one or more O levels, 9.72% had one or more A levels, just more than 37% had

[14] These seven cases were individuals whose mothers were aged less than 45 at the interview date. Of course, there might still be subsequent births of half brothers and sisters if the father has re-partnered, but we cannot do anything about this possibility. However, we do control for parental birth cohorts in addition to child cohorts. This is potentially important, as—controlling for child cohort—the parents of first-born children are likely to be younger than parents of third or fourth born.

Table 3 Education level by total number of children in the family (age 28–55)

Total number of children (including the respondent) in the family, for those aged 28–55 in 2003

Education Level	1	2	3	4	5	6	7	8	9	≥10	Total
No defined qf	63	172	196	177	144	99	67	48	34	75	1,075
	(10.21%)	(7.35%)	(10.10%)	(15.51%)	(21.69%)	(24.69%)	(31.75%)	(35.04%)	(35.42%)	(43.10%)	(13.92%)
Other qf	38	123	151	98	50	31	19	15	8	18	551
	(6.16%)	(5.25%)	(7.78%)	(8.59%)	(7.53%)	(7.73%)	(9.00%)	(10.95%)	(8.33%)	(10.34%)	(7.14%)
O Levels	132	387	344	239	133	74	33	26	14	26	1,408
	(21.39%)	(16.53%)	(17.73%)	(20.95%)	(20.03%)	(18.45%)	(15.64%)	(18.98%)	(14.58%)	(14.94%)	(18.23%)
A Levels	60	310	252	106	80	37	16	11	9	11	892
	(9.72%)	(13.24%)	(12.99%)	(9.29%)	(12.05%)	(9.23%)	(7.58%)	(8.03%)	(9.38%)	(6.32%)	(11.55%)
Other higher qf	229	796	623	368	187	111	54	24	25	34	2,451
	(37.12%)	(34.00%)	(32.11%)	(32.25%)	(28.16%)	(27.68%)	(25.59%)	(17.52%)	(26.04%)	(19.54%)	(31.74%)
Degree or above	95	553	374	153	70	49	22	13	6	10	1,345
	(15.40%)	(23.62%)	(19.28%)	(13.41%)	(10.54%)	(12.22%)	(10.43%)	(9.49%)	(6.25%)	(5.75%)	(17.42%)
Total	617	2341	1,940	1,141	664	401	211	137	96	174	7,722

Source: British Household Panel Study, wave 13 (percentages may not add to 100 owing to rounding)

Table 4 Education level by respondent's birth order (age 28–55)

Respondent's birth order within the family, for all individuals aged 28–55 in 2003												
Education level	Only child	Eldest	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth	Ninth	Tenth	Total
No defined qf	63	257	252	205	107	53	52	38	16	12	20	1,075
	(10.21%)	(10.44%)	(10.95%)	(17.37%)	(20.78%)	(19.92%)	(33.12%)	(38.38%)	(30.19%)	(33.33%)	(57.14%)	(13.92%)
Other qf	38	168	153	88	44	24	12	10	6	6	2	551
	(6.16%)	(6.82%)	(6.65%)	(7.46%)	(8.54%)	(9.02%)	(7.64%)	(10.1%)	(11.32%)	(16.67%)	(5.71%)	(7.14%)
O Levels	132	405	415	226	119	48	24	14	15	4	6	1,408
	(21.39%)	(16.45%)	(18.03%)	(19.15%)	(23.11%)	(18.05%)	(15.29%)	(14.14%)	(28.3%)	(11.11%)	(17.14%)	(18.23%)
A Levels	60	296	285	149	54	23	13	3	2	6	1	892
	(9.72%)	(12.02%)	(12.38%)	(12.63%)	(10.49%)	(8.65%)	(8.28%)	(3.03%)	(3.77%)	(16.67%)	(2.86%)	(11.55%)
Other higher qf	229	786	764	352	136	92	47	23	10	7	5	2,451
	(37.12%)	(31.93%)	(33.19%)	(29.83%)	(26.41%)	(34.59%)	(29.94%)	(23.23%)	(18.87%)	(19.44%)	(14.29%)	(31.74%)
Degree or above	95	550	433	160	55	26	9	11	4	1	1	1,345
	(15.4%)	(22.34%)	(18.81%)	(13.56%)	(10.68%)	(9.77%)	(5.73%)	(11.11%)	(7.55%)	(2.78%)	(2.86%)	(17.42%)
Total	617	2,462	2,302	1,180	515	266	157	99	53	36	35	7,722

Source: British Household Panel Study, Wave 13 (percentages may not add to 100 owing to rounding) other higher qualifications, and 15.4% have degree or above. The second column shows highest educational achievement in two-child families, the median family type for our sample. This family type has the largest percentage, 23.62%, of any family type with a degree or above, followed by 19% for the three-child family (compared with 15% for the one-child family).

There are two main points to draw from inspection of the cross-tabulations in Table 3. First, larger families are relatively rare in Britain. Second, education achievement is typically declining in family size. In sum, Table 3 suggests a trade-off to "quality" as measured by education achievement and quantity as measured by family size, as first suggested by Becker (1960). It remains to be seen in subsequent sections of this paper if this remains the case after controlling for other important education-enhancing variables. Finally, Table 4 cross-tabulates the child's birth order by the respondent's highest educational qualification. It shows that 15% of only children have a degree or above, compared with 22.34% of the first born.

4 The estimates

4.1 Specifying a new birth order index

A challenge in estimation of birth order and family size effects is that birth order is related to family size. The first born in any family always has a higher probability of being in a small family than those children born later in the birth order. And conversely, the last born has a higher probability of being in a large family than the first born. Indeed, in the BHPS data, the simple correlation coefficient between family size and birth order is 0.7047. Although studies estimating separate birth order and family size effects typically include dummy variables for birth order and a separate continuous variable for family size, this does not completely purge the family size effect from the birth order effect. Below, we put forward a simple specification of a birth order index that improves on most of the methods used in the literature to date and which we subsequently utilise in our estimation. By construction, our index effectively purges family size from birth order, and consequently, the simple correlation coefficient between family size and our birth order *index* in our data is just 0.066. This compares very favourably with the high correlation between family size and birth order of 0.705. It also compares very favourably with the Erjnaes and Portner (2004) *relative* birth order measure, which yields a simple correlation between family size and birth order of 0.354 using our data.

Suppose N denotes the total number of siblings in the respondent's family including the respondent, ϕ is the absolute birth order of the respondent, and A denotes average birth order in each family. Thus, the absolute birth order variable ϕ takes the value 1 for the first born, 2 for the second born, and so on, up to a top value of 10 for the tenth born and above. "Only" children are assigned the same birth order as first-born children. Average birth order A is calculated as $(N+1)/2$ and is clearly increasing in family size and bounded between 1 and 5.5.[15]

[15] For a one-child family, average birth order A=1, for a two-child family, A=1.5, for a three-child family A=(3+1)/2=2, and so on, up to a total value for the ten-child family of A=(10+1)/2=5.5.

If siblings were assigned equal shares in the family's educational resources (which might be both psychological and pecuniary), then the amount available for each sibling's education would depend on total family resources and family size.[16] However, as noted earlier, there are a number of arguments in the literature suggesting that equal shares are unlikely. For this reason, we wish to introduce a *birth order index* to capture the fact that resources assigned to siblings of different birth order may be different. Let B denote this index, where $B=\phi/A$; that is, B is the ratio of the respondent's birth order to the average birth order of her family, and for our data, $B\in(0.18, 1.82)$.[17] Notice that by construction, the within-family mean of $B=1$ is the same across all family types. Thus, $B=1$ represents both the within-family and across-family mean. Deflating birth order ϕ by average birth order within the family A ensures that our constructed birth order index B is independent of family size.

Let an individual's educational level be denoted as E. Suppose this is affected not only by family resources but also by the number of children in the family N, and assume that educational quality is declining in family size. As noted in Section 1, there are a number of hypotheses suggesting that birth order might have either a positive or negative effect on educational attainment. The main goal of our specification was to ensure that family size N and our index of birth order B are as little correlated as possible. Our estimating equation is:[18]

$$E_i = x_i'\omega + \alpha N_i + \beta B_i + \varepsilon_i \tag{1}$$

The sign of α is expected to be negative, and the sign of β will be revealed by the data and will tell us whether shares are larger for children born earlier or later in the birth ordering. Included in the $\boldsymbol{x}$ vector are demographics (age cohorts, gender dummy, ethnic background dummies) plus family resources variables. As we do not have a measure of family wealth when the respondent was living at home, we instead use whether or not the father and mother each had a degree as a proxy for family wealth and also whether or not the mother was in work when the child was 14, as well as the other family background variables indicated in Table 1.

We estimate two broad variants of Eq. 1—first, an ordered probit of highest educational attainment, and second, ordinary least squares (OLS) estimates of the natural logarithm of years of education. Notice that Eq. 1 nests within it the possibility of equal shares between siblings, as, if $\beta=0$, birth order will have no

[16] It is well known that the children of wealthy parents receive more and better quality schooling than children of poorer families and that the family environment is also important (see inter alia the survey by Bowles and Gintis 2002; Hauser and Sewell 1985; Hauser and Kuo 1998; Kaestner 1997 and Kessler 1991). Our goal here was additionally to look at *intra-family* differences while controlling for family wealth and the family environment.

[17] To illustrate, concider four family types: one-child, two-child, three-child and ten-child. For the only child from a one-child family, $B_{11}=1$, where the first subscript denotes birth order and the second family size. Now concider the first-born child from a two-child family. Her index is $B_{12}=1/1.5=0.666$. For the second-born child, $B_{22}=2/1.5=1.333$. Next, take a three-child family. The first born has $B_{13}=0.5$, the second born has $B_{23}=1$, while the third born has $B_{33}=3/2=1.5$. Finally, consider a ten-child family. Here, the first born has $B_{1,10}=1/(5.5)=0.182$, the second born has $B_{2,10}=2/(5.5)=0.364$, the third born has $B_{3,10}=3/(5.5)=0.545$, the ninth born has $B_{9,10}=9/(5.5)=1.636$, while the tenth born has $B_{10,10}=10/(5.5)=1.818$.

[18] This is analogous to fixed-effects estimation in that the birth order effect is estimated as deviations from the within-family-size mean of unity. Thus, in, for example, a ten-child family, half of the observations will be above the mean and half below the mean. Deviations from the mean yield the birth order effect.

effect on educational attainment. However, if $\beta<0$, the first-born sibling will receive a greater share than subsequent children, while if $\beta>0$, the last-born sibling will receive a greater share than earlier children. Of course, this specification does impose the restriction that the sharing rule is monotonic.[19] Later, we relax this restriction and allow the sharing rule to be non-monotonic.

Appendix B reports the predicted and actual means and variances of B broken down by the ten family size categories (the predicted means and variances are based on the assumption that all children in each family appear in the data, which does not happen in the sample, and this is why there are some differences). Note that the actual means from our data are all very close to one. As estimation of the average birth order effect purged of family size relies on the fact that the average value of B is one, this is reassuring. Appendix B shows that the actual variances for each size of family are typically slightly less than the predicted variances.

It is possible that the 'sharing rule' described above is non-monotonic, and in this case, estimation of a functional form such as that implied by Eq. 1 may be inappropriate. To test for this, we also wish to estimate a more flexible functional form. We do this by dropping from our estimating subsample all those children who are from an only-child family. We then include, instead of the birth order index B, two dummy variables, which we denote by D_1 and D_2. The first, D_1, takes the value 1 for all individuals whose birth order index $B<0.8$ and 0 otherwise. The second dummy, D_2, takes the value 1 for all individuals whose birth order index $B>1.2$ and 0 otherwise. Thus, the base group is effectively the middle child in an odd-numbered family and the two middle children in an even-numbered family (except for the two-child family in which there is no child in the base group). A simple test of the monotonic specification is that γ_1 and γ_2 in the following equation are of opposite signs:

$$E_i = x_i'\omega + \alpha n_i + \gamma_1 D_1 + \gamma_2 D_{2i} + \varepsilon_i \tag{2}$$

We expand on this in Section 4.3, but first we present the estimates of Eq. 1.

4.2 The initial estimates

Table 5 presents estimated coefficients from an ordered probit of educational attainment where the dependent variable is categorical (1 denotes the lowest educational category and 6 denotes the highest). The means for each level of education are given in Table 1. We present four specifications in Table 5. Specification [1] does not include any family composition variables, while Specification [2] adds in the family size. Specification [3] estimates Eq. 2 above, and thus, includes both family size and the birth order index. Specification [4] reestimates [3] over a subsample excluding respondents from only-child families. All four specifications include dummy variables for the child's age cohort (with the base being 28–33 years old), female, parental family resources (father had a degree; mother had a degree, whether or not mother worked when child was aged 14) and eight additional dummy variables

[19] For example, in a three-children family with $\beta<0$, the first born will receive the biggest share, the second born the second biggest share and the third born the smallest share. If $\beta>0$, the ordering is reversed. A practical way of ascertaining the monotonicity of a given function $y=f(x)$ is to check whether the derivative $f'(x)$ always adheres to the same algebraic sign for all values of x. See for example Chiang (1984).

Table 5 Specifications [1] to [4], highest educational attainment (categorical education qualification as dependent variable)

	Spec [1]	Spec [2]	Spec [3]	Spec [4]
Demographics				
Age 34–39	−0.07 (1.93)*	−0.046 (1.26)	−0.049 (1.34)	−0.03 (0.79)
Age 40–45	−0.141 (3.83)***	−0.084 (2.26)**	−0.102 (2.75)***	−0.083 (2.15)**
Age 46–50	−0.133 (3.28)***	−0.075 (1.84)*	−0.105 (2.55)**	−0.077 (1.79)*
Age 51–55	−0.356 (8.69)***	−0.318 (7.74)***	−0.35 (8.47)***	−0.319 (7.32)***
Female	−0.199 (8.13)***	−0.181 (7.36)***	−0.179 (7.27)***	−0.178 (6.93)***
Non-white	0.4 (5.31)***	0.478 (6.33)***	0.467 (6.18)***	0.495 (6.34)***
Family attributes				
Mum degree	0.555 (10.82)***	0.551 (10.59)***	0.53 (10.25)***	0.582 (10.00)***
Dad degree	0.267 (8.47)***	0.265 (7.37)***	0.253 (7.30)***	0.204 (6.98)***
Quite a few books	0.375 (8.32)***	0.374 (6.83)***	0.368 (6.70)***	0.283 (6.50)***
Lots of books	0.592 (14.41)***	0.579 (12.62)***	0.568 (12.33)***	0.486 (11.91)***
Kid inner	−0.201 (4.36)***	−0.162 (3.51)***	−0.161 (3.48)***	−0.169 (3.51)***
Kid town	−0.176 (5.15)***	−0.154 (4.52)***	−0.15 (4.39)***	−0.151 (4.23)***
Kid village	−0.198 (5.38)***	−0.187 (5.06)***	−0.182 (4.93)***	−0.168 (4.36)***
Kid rural	−0.252 (5.96)***	−0.176 (4.13)***	−0.187 (4.38)***	−0.183 (4.12)***
Kid mobile	0.093 (1.54)	0.102 (1.69)*	0.1 (1.64)	0.114 (1.78)*
Working mum	0.029 (1.14)	−0.022 (0.88)	−0.008 (0.32)	−0.012 (0.47)
Family composition				
Family size		−0.102 (15.28)***	−0.101 (15.15)***	−0.113 (15.44)***
Birth order index			−0.263 (7.45)***	−0.26 (7.21)***
Parental cohorts	Yes	Yes	Yes	Yes
Observations	7,722	7,722	7,722	7,105
Wald χ^2	1,222.22	1,456.93	1,512.46	1,450.24
Log likelihood	−12448.094	−12330.739	−12302.974	−11325.734
Pseudo R^2	0.0468	0.0558	0.0579	0.0602

Source: British Household Panel Study, Wave 13. Absolute value of t statistics in parentheses. Parental age cohorts include mum2125–mum41up, dad2125–dad41up, with mum20 and dad20 as base groups, respectively.

*Significant at 10%

**Significant at 5%

***Significant at 1%

representing the ages of the mother and father respectively at the child's birth. Also included is a set of variables picking up family level attributes (presence of books when the child was young and area of the parental home).[20]

Some mothers have their first born when they are teenagers, whereas others have their first birth in their late thirties. These maternal age differences might translate into different inputs of time, energy and experience, which may affect children's educational attainment quite distinctly from birth order effects. The inclusion of parental age cohorts at child's birth allows us to investigate this issue. We find in Specification [1] in Table 5 that these parental age cohort variables are individually[21]

[20] We also experimented with including a dummy variable taking the value one if the child lived with both biological parents from birth to age 16. As this was insignificantly different from zero, we dropped this from our reported models in Tables 5 and 6. Children who grew up with both parents are no different in terms of educational attainment from those who did not for our sample of British children.

[21] The only exception is the dummy variable for mother aged between 21 and 25 years old at the respondent's birth.

and jointly statistically significant. Relative to the base group of mothers or fathers aged less than 21 at the child's birth, children whose parents were older at their birth have increasingly higher levels of educational attainment.

The estimates show that the child's educational attainment is declining with age. The fact that younger cohorts have higher educational attainment is expected, owing to the relatively recent expansion of education in Britain.[22] Note that the cohort effects are also likely to capture some family size effects if families in Britain have become smaller over time. But the age cohorts should not affect the coefficient on the birth order index, as the mean value of this index will not be correlated with cohort (its mean is always 1).

Specification [1] also shows that the child's educational attainment is lower if the child is female and is increasing in the parents' educational level, especially so if the mother had a degree. Educational attainment is increasing with the presence of books in the parental home (the base is not many books in the house when the child was between 0 and 10) and is declining if the child did not live in suburbia (this probably proxies parental wealth).[23] Furthermore, respondents from a non-white ethnic group have significantly higher education attainment.

Specification [2] augments Specification [1] with the inclusion of the family size. The estimates show that as expected, a child's educational attainment is declining in family size. The estimated coefficient is −0.102 (t statistic −15.28). Specification [3] replicates Specification [2] but with the addition of the birth order index. The coefficient to family size is now −0.101 (t statistic −15.15), while the coefficient to the birth order index is −0.263 (t statistic −7.45). As discussed below Eq. 1, the statistically significant negative coefficient to the latter suggests that lower birth order children receive a greater share of family resources than higher birth order siblings. The fact that we cannot accept the hypothesis that $\beta=0$ suggests that family resources are not shared equally across all siblings. The coefficient to family size is very similar to that found in Specification [2].

Respondents from single-child families are included in estimation of Specifications [1] to Specification [3]. However, it might be argued that our variables of interest affect educational outcomes differently for children from single-child families compared with those from multiple-children families. To examine this issue, we exclude respondents from a single-child family in Specification [4]. The sample size reduces from 7,722 to 7,105. Notice that after the exclusion of single-child respondents, the family size effect becomes more negative, as expected. The coefficient of the family size is now −0.113 (t statistic −15.44). In addition, we find

[22] We also reestimated all the specifications on separate older and younger subsamples. The first comprised individuals aged 42–55, and the younger subsample comprised individuals 28–41. Our results were robust to this reestimation. Hence, in the interests of space, we do not report them here.

[23] To avoid throwing out cases with missing information on family background variables, we constructed dummy variables for missing information for each relevant variable. It is possible, e.g. that children whose mother had a low-level qualification might be less likely to know what it was, and we control for this. Thus, for the maternal highest educational qualification, the respondent was first asked if they knew their mother's qualification. If they did not, we included a dummy reflecting this. The respondent was then—conditional on knowing their mother's qualification—asked what it was. We therefore constructed another dummy for this. We do not, however, report the coefficients to these missing information variables in the tables in the interests of space. Note that all the variables for parental qualifications and numbers of books in the house are conditional on reporting information, and the coefficients should be interpreted in line with this. There is, however, no missing information for area of childhood home.

that the coefficient to the birth order index remains unchanged compared to Specification [3]. This supports our finding that lower birth order children receive a greater share of family resources than higher birth order siblings; the inclusion of single-child families in our sample does not alter the estimates.[24]

It is also interesting to compare the results from using our own birth order index with those obtained using the Ejrnaes and Portner (2004) relative birth order measure—henceforth EP—which is constructed as $[(\phi-1)/(N-1)]$. In our full estimating sample of 7,722 observations, the simple correlation between family size and the EP index is 0.354. In contrast, the simple correlation between family size and our own birth order index is just 0.066, as we noted in Section 4.1. As a comparison, we also estimated Specification [4] (which omits one-child families following Erjnaes and Portner) using the EP relative birth order index.[25] The coefficient to family size in this regression was −0.1002 (t statistic −13.42), which is similar to the result from our model (see Specification [4] in Table 5). However, the coefficient to the EP relative birth order index was −0.4095 (t statistic −7.48). This is nearly twice as large in absolute terms as the estimated coefficient obtained using our own birth order index, which has a very much lower correlation with family size.

The coefficients of the ordered probit model cannot be translated directly. To facilitate interpretation, predicted probabilities of individuals' educational outcome and marginal effects are reported in Table 6. This table—based on Specification [4] that excludes only-child families—compares the differences in predicted educational outcomes of being the middle child and first born in the family (but notice that we exclude two-children families in calculating the middle child probabilities). Our model predicts that a middle child has a 19.3% probability of obtaining 'undefined' qualifications and an 8.58% probability of obtaining a 'degree or above'. In contrast, being first born in the family is associated with a 12.46% probability of obtaining an 'undefined' qualification and a 13.96% probability of obtaining a degree or higher qualification.

It is also interesting to consider the effects of some of the other variables. Table 7 reports marginal effects, using Specification [3], of having parents with higher education, of parental age when respondent was born, of living area during the respondent's childhood and of gender and ethnic group. Ceteris paribus, having older—or more educated parents—increases educational attainment, as does being male, non-white and being brought up in suburbia.

In summary, our results reported in Table 5 suggest that birth order matters. But so too does family size, in contrast to the results of Black et al. (2005) using Norwegian data. This difference may reflect different institutions and policies across the two countries. It is also interesting that our estimates show no statistically significant effect of having a working mother when the child was aged 14. However,

[24] As family size is potentially endogenous (see inter alia Cigno and Ermisch 1989, and Barmby and Cigno 1990), we also estimated two additional separate equations for each of Specifications [3] and [4] in which we dropped family size and included only the birth order index. These are essentially reduced form equations. We find that the estimated coefficients of the birth order index changed slightly, from −0.263 in Specification [3] and −0.260 in Specification [4] to −0.272 and −0.262 in Specifications [3] and [4], respectively. Both coefficients remained statistically significant at the 1% level.

[25] In this smaller subsample of 7,105 observations, the simple correlation between family size and the EP index is 0.27, while the simple correlation between family size and our own birth order index is just 0.07.

Table 6 Predicted probabilities

Education level	Middle child[a] (%)	First born (%)
No defined qf	19.30	12.46
Other qf	9.92	7.80
O levels	22.41	20.08
A levels	12.71	12.93
Other higher qf	27.09	32.78
Degree or above	8.58	13.96

Estimated probabilities are based on the coefficients obtained from Specification [4].
[a] Middle child is defined as the middle child in an odd-numbered family and the two middle children in an even-numbered family. Two-children families excluded.

there is a positive correlation between a child's educational attainment and the two variables for the highest level of mother's and father's education. These latter variables are likely to pick up family wealth effects, but probably also reflect family-level effects, such a supportive background for education. But one of the most important explanatory variables of children's educational attainment remains our proxy for family fixed effects—the presence of many books in the household when the child was aged between 0 and 10 years. In Section 5, we report the results from a number of extensions to the basic models, including allowing for potential endogeneity of family size.

4.3 Checking for non-monotonicity

Our estimates of the impact of the birth order index imposed monotonicity, as we estimated only one slope coefficient. We found that educational attainment was declining in the birth order index, indicating negative monotonicity. But it is possible

Table 7 Marginal effects

Education level	Educated parents (%)	Younger parents[a] (%)	Older parents[b] (%)	Suburban area (%)	Male (%)	Non-white (%)
No defined qf	−12.33	7.58	−7.06	−3.41	−4.01	−8.92
Other qf	−5.48	1.85	−2.61	−1.13	−1.35	−3.50
O levels	−9.51	1.38	−3.62	−1.37	−1.76	−5.23
A levels	−2.58	−0.76	−0.34	−0.03	−0.01	−0.80
Other higher qf	8.99	−5.96	6.06	2.93	3.45	7.50
Degree or above	20.91	−4.08	7.58	2.95	3.58	10.95

Estimated probabilities are based on the coefficients obtained from Specification [3]. Estimated marginal effects are relative to the base group in which the base group is set to the mean of the sample. In other words, base group is a respondent between the age of 34 and 39, a female, parents with no higher education, had quite a few books at home, lived in town area, mother worked, dad aged between 34 and 40 when respondent was born, mum's age was 21–25 when respondent was born, is white.
[a] "Younger parents" means respondent's parents are less than or equal to 21 years old when respondent was born.
[b] "Older parents" means respondent's parents are older or equal to 41 years old when respondent was born.

that the relationship between educational attainment and birth order could be non-monotonic, and this would not be picked up by the coefficient to the birth order index. Therefore, in this subsection, we report the results of conducting the specification test discussed at the end of Section 4.1. Our results are presented in Table 8. Recall that $\gamma_1 > 0$ implies that children with a relatively lower birth order in their family attain higher levels of education (relative to the base of the middle child/ren), whereas $\gamma_2 < 0$ implies that children with a relatively higher birth order than the base group receive lower levels. Hence, if $\{sign\ \gamma_1\} \neq \{sign\ \gamma_2\}$, then the relationship between educational attainment and birth order is monotonic. For negative monotonicity, we require that $\gamma_2 > 0$ and $\gamma_2 < 0$, and vice versa for positive monotonicity. If the signs of both coefficients were the same, we would know our data indicate a non-monotonic relationship between educational attainment and birth order.

The estimates reported in Table 8 exclude single-child families (thus, the subsample comprises 7,105 cases). The base group is the middle child in an odd-numbered family and the two middle children in an even-numbered family (for the two-child family, there is no child in the base group). Our estimates show $\widehat{\gamma}_1 = 0.122$ (*t*-statistic 3.33) while $\widehat{\gamma}_2 = 0.098$ (*t*-statistic −2.64). These are both statistically significant at the 1% level. In

Table 8 Test for non-monotonicity

Dependent variable: categorical highest education qualification (only-child respondents excluded)	
Demographics	
Age 34–39	−0.029 (0.76)
Age 40–45	−0.077 (1.98)**
Age 46–50	−0.069 (1.61)
Age 51–55	−0.309 (7.10)***
Female	−0.178 (6.93)***
Nonwhite	0.503 (6.46)***
Family attributes	
Mum degree	0.581 (10.04)***
Dad degree	0.205 (6.99)***
Quite a few books	0.283 (6.48)***
Lots of books	0.484 (11.86)***
Kid inner	−0.169 (3.50)***
Kid town	−0.15 (4.21)***
Kid village	−0.169 (4.37)***
Kid rural	−0.18 (4.07)***
Kid mob	0.115 (1.81)*
Working mum	−0.015 (0.57)
Family composition	
Family size	−0.112 (15.19)***
$\gamma_1 D_1$	0.122 (3.33)***
$\gamma_2 D_2$	−0.098 (2.64)***
Parental cohorts	Yes
Observations	7,105
Wald χ^2	1,444.92
Log likelihood	−11,328.394
Pseudo R^2	0.0600

Absolute value of t statistics in parentheses

*Significant at 10%

**Significant at 5%

***Significant at 1%

other words, educational attainment is declining in birth order, indicating negative monotonicity. This was also found with our estimates using the birth order index.[26] These results imply that not only are available educational resources not shared equally among children within a family, but that first born and elder children tend to receive greater share of educational resources compared to their subsequent siblings in the family.[27]

5 Robustness checks

5.1 Years of education as the dependent variable

We now replace the ordered dependent variable with the natural logarithm of years of education and replicate, using OLS, all four specifications reported in Table 5. These results are reported in Table 9 as Specifications [1a] to [4a]. Our preferred specifications are, as for the ordered probit models, Specifications [3] and [4a]. Specification [5a] reports our two-stage least-squares results when we allow for family size to be endogenous. We discuss these instrumental variables (IV) estimates later in this subsection.

The estimates show that years of education are significantly lower for children in the age group 51–55 than in the younger age groups, are lower for women than for men and are higher for people of non-white ethnic background. Years of education are significantly increasing in the parents' educational level (especially so if the mother had a degree), with the presence of many books in the parental home, and if the child's family moved around, and are declining if the child did not live in suburbia (suburbia is the base). Importantly, years of education of the child are significantly declining in family size, and lower birth order children receive a greater share of family resources than do higher birth order siblings. Thus, the results are consistent with those reported in the previous section.

Specification [5a] in Table 9 reports estimates of an IV model, which we estimated because family size is potentially endogenous. This was estimated by 2SLS. We use parental birth cohorts, parent's age difference and residential area during childhood as our instruments.[28] The family size effect becomes more negative (changing from −0.013 to −0.024, with a *t* statistic of −4.4), and the birth order effect becomes slightly less negative (changing from −0.034 to −0.012 with a *t* statistic of

[26] We also reestimated the model on a subsample of larger families (with at least three children and above) to test for family size non-monotonicity. We find that our results are very similar under this new stratification. This suggests that our result is not simply picking up a size effect from family size of two and above.

[27] We also experimented with estimating this model using the entire sample of 7,722 cases. Here, the children from only-child families are included in the base group (as their birth order index takes the value 1). The estimates from this specification were that $\gamma_1>0$, but that γ_2 is insignificantly different from zero. This was the case regardless of how we specified family size (i.e. as linear or inverse). These results suggest that 'only children' may do worse than the first or high born in multi-children families, a result that Iacavou (2001) also found. This could arise if sibling input matters. But if so, it matters asymmetrically across family members.

[28] To test the suitability of our instruments, a regression with family size as the dependent variable and the instruments as explanatory variables was estimated. We found that the instruments are statistically significant as a group in explaining family size.

Table 9 Ln of years of schooling

	Spec [1a]	Spec [2a]	Spec [3a]	Spec [4a]	Spec [5a]
Demographics					
Age 34–39	−0.007 (1.34)	−0.004 (0.76)	−0.004 (0.82)	−0.002 (0.39)	−0.002 (0.32)
Age 40–45	−0.012 (2.23)**	−0.005 (0.9)	−0.007 (1.33)	−0.004 (0.8)	0.002 (−0.34)
Age 46–50	−0.02 (3.40)***	−0.012 (2.16)**	−0.016 (2.80)***	−0.013 (2.16)**	−0.007 (1.02)
Age 51–55	−0.052 (9.09)***	−0.047 (8.24)***	−0.051 (8.92)***	−0.047 (7.84)***	−0.045 (6.64)***
Female	−0.029 (8.34)***	−0.026 (7.63)***	−0.026 (7.56)***	−0.026 (7.29)***	−0.022 (5.84)***
Nonwhite	0.06 (5.77)***	0.069 (6.65)***	0.067 (6.51)***	0.07 (6.63)***	0.071 (6.29)***
Family Attributes					
Mum degree	0.076 (10.06)***	0.075 (9.85)***	0.072 (9.52)***	0.079 (9.42)***	
Dad degree	0.034 (8.03)***	0.033 (7.08)***	0.032 (7.01)***	0.024 (6.52)***	
Quite a few books	0.036 (7.09)***	0.034 (5.79)***	0.032 (5.66)***	0.02 (5.55)***	0.060 (5.64)***
Lots of books	0.068 (13.71)***	0.065 (12.12)***	0.062 (11.86)***	0.05 (11.55)***	0.103 (12.09)***
Kid inner	−0.028 (4.28)***	−0.023 (3.55)***	−0.023 (3.53)***	−0.023 (3.46)***	
Kid town	−0.021 (4.43)***	−0.019 (3.88)***	−0.018 (3.75)***	−0.018 (3.54)***	
Kid village	−0.023 (4.49)***	−0.022 (4.19)***	−0.021 (4.07)***	−0.018 (3.39)***	
Kid rural	−0.033 (5.52)***	−0.024 (3.96)***	−0.025 (4.19)***	−0.024 (3.93)***	
Kid mobile	0.018 (2.10)**	0.019 (2.24)**	0.018 (2.20)**	0.022 (2.45)**	
Working mother	0.001 (0.28)	−0.005 (1.46)	−0.003 (0.93)	−0.004 (1.12)	−0.010 (1.68)*
Family Composition					
Family size		−0.012 (13.10)***	−0.012 (12.98)***	−0.013 (13.52)***	−0.024 (4.4)***
Birth order index			−0.034 (6.94)***	−0.034 (6.82)***	−0.012 (2.62)*
Constant	2.517 (129.12)***	2.548 (131.16)***	2.582 (129.28)***	2.6 (121.30)***	2.629 (111.4)***
Parental Cohorts	Yes	Yes	Yes	Yes	Yes (As IV)
Observations	7722	7722	7722	7105	7722
F-stat	44.43	49.93	50.16	48.52	59.62
R-sq	0.1349	0.1538	0.1590	0.1659	0.090
Adj R-sq	0.1318	0.1507	0.1559	0.1625	0.089

Absolute value of *t* statistics in parentheses. Parental age cohorts include mum2125–mum 41up, dad2125–dad41up, with mum20 and dad20 as base groups, respectively. Instruments are parental birth cohorts, parents' age difference and residential area during childhood

*Significant at 10%

**Significant at 5%

***Significant at 1%

−2.62). Unfortunately, we do not have better instruments available to check for potential bias. Ideally, we would like to use a dataset containing information not only on twins within the same family but also on birth weight and related factors, as argued by Rosenzweig and Zhang (2006). Such data are not yet available for Britain.

5.2 Other extensions

We next return to our ordered probit model of highest educational attainment and estimate a number of extensions. The results are presented in Table 10. Specification [3] is repeated for ease of comparison.

5.2.1 Gender

First, we test the hypothesis that there are significant gender differences for men and women by interacting all of our variables with female. The results are reported in the second column of Table 10 as Specification [5]. Only a few of the interactions are

Table 10 Models with interaction terms (categorical education qualification as dependent variable)

	Spec [3] Preferred Model	Spec [5] Gender Interaction	Spec [6] Famnorm Dummy	Spec [7] Famnorm Interaction	Spec [8] Workmum Interaction	Spec [9] Mum_deg Interaction
Family size	−0.101 (15.15)***	−0.105 (10.29)***	−0.101 (15.15)***	−0.073 (4.67)***	−0.099 (12.41)***	−0.104 (14.59)***
Birth order index (BO)	−0.263 (7.45)***	−0.188 (3.62)***	−0.263 (7.44)***	−0.220 (2.65)**	−0.217 (4.88)***	−0.212 (5.50)***
Family size × female		−0.007 (0.48)				
BO × female		−0.140 (1.97)*				
Famnorm			0.007 (0.21)	0.545 (1.72)*		
Fam size × famnorm				−0.034 (1.99)**		
BO × famnorm				−0.052 (0.56)		
Workmum					0.172 (0.59)	
Fam size × workmum					−0.006 (0.39)	
BO × workmum					−0.142 (1.92)*	
Mumdeg						0.194 (3.51)***
Fam size × mumdeg						0.024 (1.18)
BO × mumdeg						−0.312 (3.22)***
Observations	7,722	7,722	7,722	7,722	7,722	7,722
Wald/LR χ^2	1,512.46	1,573.02	1,512.51	1,543.02	1,538.37	1,557.98
Log likelihood	−12,303.0	−12,272.7	−12,303.0	−12,287.69	−12,290.02	−12,280.22
Pseudo R^2	0.0579	0.0581	0.0559	0.0591	0.0589	0.0579

Absolute value of t statistics in parentheses
*Significant at 10%
**Significant at 5%
***Significant at 1%

individually statistically significant, although they are jointly statistically significant as a group. A comparison of Specification [3] with Specification [5] reveals that the coefficient of family size remains virtually unchanged and is still statistically significant. However, the negative effect of birth order has reduced to −0.188 (*t* statistic −3.62) in Specification [5]. The negative coefficient of the interaction term suggests that higher birth order disadvantages females' educational attainment more than males. This also implies that birth order is a more important factor in explaining females' educational outcomes, although this is not statistically significant individually.

5.2.2 Non-white

We next experiment with including interactions of the dummy variable for non-white. Only 2.6% of the sample is non-white, as Table 1 shows. They are a very heterogeneous group, but the cell sizes when we disaggregate this variable into its component ethnic groups are too small for us to include as separate variables. We initially experimented with interacting non-white with all of the explanatory variables, but the interactions were neither individually nor jointly statistically significant. We then included non-white as a single explanatory variable and found that it significantly increased the probability of higher educational attainment, as reported earlier in Tables 5 and 9. But this had no effect on the magnitude of the family composition variables: family size and birth order remain statistically significant and negative.

5.2.3 Lived with both biological parents from birth to age 16

We now test the hypothesis that family size and birth order effects might differ for children being brought up in a 'normal' family home (where both natural parents are present at least until the child was aged 16) as compared with the base group of the rest.[29] It is possible that children from very small families are more likely to be from broken homes, and children with separated parents might have lower educational attainment. We investigated this hypothesis, as reported in Specifications [6] and [7] of Table 10. This 'family normal' group represents 82% of the sample, as shown in Table 1. Specification [6] presents the estimates of educational attainment when we include a dummy variable, taking the value 1 when the child grew up with both biological parents and 0 otherwise.[30] The estimated coefficient is positive but not statistically significant, and its inclusion has little appreciable impact on our estimated family size and birth order effects. We then interacted 'family normal' with all the explanatory variables, and the results for our variables of interest are shown in Specification [7]. We find that these interactions are neither jointly nor individually significant, and our family size and birth order effects have a slightly less negative effect on education outcomes as compared to Specification [3]. We also, as suggested by a referee, estimated the model only on the subsample of 6,239 individuals who grew up in a "normal" family. As this made little difference to our results, we do not report them here.

5.2.4 Working mother

We next experiment with interacting all our explanatory variables with whether or not the child's mother was working when the child was aged 14.[31] Table 1 shows that 39% of our sample had mothers in this category. Working mothers may be less financially constrained than non-working mothers—but on other hand, maternal input into child 'quality' may be lower, as they are time-constrained (Birdsall 1991). These results are reported in Table 10 as Specification [8]. Again, we find that the inclusion

[29] The question takes the form: "Did you live with BOTH your biological mother AND biological father from the time you were born until you were 16?"

[30] This control is not ideal, as it does not account for the possibility of living with other stepsiblings that arise from parents' re-marriages. In other words, we still cannot rule out the possibility that parents might tend to invest more resources in their biological children rather than stepsiblings from remarriages.

[31] The simple correlation coefficient between mother working and mother with a degree is quite low at 0.1206.

of additional interaction terms does not make much difference to the magnitude, sign and statistical significance of the family composition variables family size and birth order. Most of the interaction terms are statistically insignificant individually (they are also insignificant as a group). However, the interaction of the birth order index with working mother is negative and is statistically significant at the 10% level.

Birdsall (1991) argued that birth order effects should be less likely among the children of working mothers who can shift in and out of work to make the shadow value of their time equal across all time periods.[32] Using 1967–1968 household data from urban Columbia, she found that birth order effects are less likely to be present among the children of working mothers for whom the direct positive effect of maternal education is also greater. We experimented with reestimating Specification [3] for a subsample comprising the 3,014 people with a working mother during childhood. Our estimates indicated the birth order effect is significantly *more* negative for children with working mothers. In the interests of space, we do not report our full results here. However, for this subgroup, while the estimated coefficient to the family size variable was −0.108 (t statistic of −8.79), the birth order effect was −0.370 (t statistic −6.24). Moreover, the effect of maternal education variable had a smaller direct effect, with a coefficient of 0.404 (5.33) as compared with 0.530 (10.25) for the full sample. Thus, our results differ from Birdsall's. Of course, her survey was 35 years older than ours and from a less developed country.

5.2.5 Mother with higher education or further education qualification

Mothers with higher educational qualifications might give their children's educational attainment greater attention and priority. Following Specification [8], we also test the hypothesis that more educated mothers might affect children's educational outcomes differently. The estimates are presented in Specification [9] in Table 10. From Table 1, 19.6% respondent reported their mother as having higher education or further education qualifications. As found with all the other interaction models, the inclusion of mother's education interaction terms does not alter the sign, magnitude and significance of the family size and birth order variables. Again, most of the interaction terms are not statistically significantly, but they are significant as a group. However, the interaction of the variable "mumdeg" with the birth order index is statistically significant and negative. Thus, the impact of birth order on children's educational attainment becomes even more negative for the children of highly educated women. It is unclear why mothers with higher education are likely to influence lower birth order children's educational attainment more positively than higher birth order children.

5.2.6 Black et al. specification

We next estimated a model including a set of explanatory variables similar to those found in Black et al. (2005: Table 4b) as a comparison. The estimates are presented in Table 11 as Specification [10]. Estimates from the Black et al. model are also listed for convenience, but note that they report SEs in parentheses. In contrast to Black et

[32] Of course, there are considerable losses in experience capital—representing a form of switching cost—for women who make these transitions. This would suggest there would be a band of inaction.

Table 11 Comparison of Black et al. (2005) model (dependent variable: education in years)

OLS	Black et al.	Spec [10]
Family size	−0.012 (0.002)**	−0.122 (7.30)***
Birth order—second	−0.29 (0.004)**	−0.068 (1.25)
Birth order—third	−0.49 (0.007)**	−0.282 (3.96)***
Birth order—fourth	−0.63 (0.10)**	−0.408 (3.99)***
Birth order—fifth	−0.72 (0.015)**	−0.057 (0.42)
Birth order—sixth	−0.78 (0.023)**	−0.338 (1.89)*
Birth order—seventh	−0.85 (0.037)**	−0.246 (1.12)
Birth order—eighth	−0.75 (0.059)**	−0.422 (1.44)
Birth order—ninth	−0.94 (0.081)**	−0.499 (1.43)
Birth order—tenth	−1.13 (0.116)**	−0.731 (2.05)**
Additional control	Yes	Yes
Observations	1,427,107	7,722
R^2	0.1989	0.1192

SEs in parentheses for the Black et al. estimates. Additional controls include age, mother's age, sex, mum_deg, dad_deg, father's age. Absolute value of *t* statistics in parentheses for our estimates.
*Significant at 10%
**Significant at 5%
***Significant at 1%

al. (2005), our estimates in Specification [10] show that the British family size effect does not vanish even after we control for birth order using their procedure. Our family size variable has a much bigger negative effect on children's educational outcomes compared to the estimates of Black et al., a coefficient of −0.122 (*t* statistic −7.30). In addition, birth order dummy variables in the model of Black et al. become systematically more negative as we move towards higher birth order ranking. We find that only four out of nine birth order dummy variables are statistically significant in Specification [10]. Furthermore, while our birth order dummy variables do become more negative at higher birth order, the effect is not systematic

5.2.7 Estimating the birth order effects separately by family size

As a final robustness check, we estimated the birth order effect by running separate regressions for each family size, which Black et al. (2005) also did using their Norwegian data. We experimented with including as controls (1) dummy variables for each level of birth order, and then separately (2) including as a control the birth order index. For case (1), there are extremely small cell sizes for the larger families, as we highlighted in discussion of Table 2 in Section 3 above. We therefore top-coded family size at seven or more children in the family. The mean of this new family size dummy variable is 0.028. For case (1), we omit from the sample only-child families, and the base or omitted birth order category for each of the six regressions is first born. The estimates are presented in Table 12. For respondents from families ranging between two and four children, the birth order effect is similar to that found in our earlier estimation: Children who are of higher birth order receive significantly less education than their older siblings. For children from larger families (five or more children), the birth order effect is always negative, with the exception of second-born children from families of six or more children. However,

Table 12 Birth order effect stratified by family sizes (categorical education qualification as dependent variable)

	Family size					
	2-Children	3-Children	4-Children	5-Children	6-Children	7+-Children
Case (1)						
Birth order						
2nd	−0.159 (3.32)***	−0.223 (3.69)***	−0.011 (0.12)	0.025 (0.18)	0.134 (0.66)	0.224 (1.13)
3rd		−0.375 (5.27)***	−0.321 (3.30)***	−0.076 (0.54)	−0.083 (0.42)	−0.273 (1.30)
4th			−0.392 (3.57)***	−0.128 (0.86)	−0.267 (1.34)	−0.252 (1.21)
5th				−0.151 (0.96)	0.210 (0.96)	0.088 (0.42)
6th					−0.305 (1.40)	−0.115 (0.56)
≥7th						−0.251 (1.34)*
Parental cohorts	Yes	Yes	Yes	Yes	Yes	Yes
Demographics	Yes	Yes	Yes	Yes	Yes	Yes
Family attributes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,341	1,940	1,141	664	401	618
LR-χ^2	332.65	372.44	165.62	106.5	110.98	122.79
Pseudo R^2	0.0439	0.057	0.0431	0.0472	0.082	0.0612
Log likelihood	−3625.064	−3081.330	−1836.906	−1073.765	−621.155	−941.869
Case (2)						
Birth order index	−0.238 (3.32)***	−0.380 (5.38)***	−0.363 (4.10)***	−0.129 (1.15)	−0.166 (1.19)	−0.240 (2.04)**
Parental cohorts	Yes	Yes	Yes	Yes	Yes	Yes
Demographics	Yes	Yes	Yes	Yes	Yes	Yes
Family attributes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,341	1,940	1,141	664	401	618
LR-χ^2	332.65	371.98	161.79	106.19	101.25	115.50
Pseudo R^2	0.0439	0.0569	0.0421	0.0471	0.0748	0.0576
Log likelihood	−3,625.064	−3,081.56	−1,838.82	−1,073.92	−626.02	−945.520

Source: British Household Panel Study, wave 13. Absolute value of *t* statistics in parentheses

*Significant at 10%

**Significant at 5%

***Significant at 1%

these effects are typically not statistically significantly, possibly owing to the small cell sizes involved in estimation.

For the six separate regressions for case (2)—in the bottom panel of Table 12—we estimate the birth order effect from deviations from the mean using the birth order index. Once more, the estimated coefficient to the birth order index is always negative. In most cases, it is also statistically significant, with the only exceptions being respondents from five- and six-children families.

5.3 Summary of our main results

In summary, our results show that ceteris paribus, educational attainment is declining in family size and in birth order.[33] In terms of our model specification, higher birth

[33] Iacovou (2001) also found, using British data from a 1958 birth cohort, that children from larger families have lower levels of educational attainment at ages 7 to age 23 and that there is an additional negative birth order effect.

order children receive a lower share of family resources in the form of educational attainment. These results were found for both our measures of educational attainment: highest level of qualification and years of schooling. The first finding, of the negative effect of family size, might be viewed as reinforcing the child quality–quantity approach. Parents trade off higher ‘quality’, as proxied by educational outcomes, against greater numbers of children. For a given level of parental income, family size is likely to reduce the per capita resources that can be spent on educational investments.

The second finding—that educational attainment is declining in birth order—could arise for a number of reasons. In Section 2 we noted some candidate hypotheses about the impact of birth order, some of which are expected to have a negative effect and some a positive effect on children who are otherwise identical. Those predicting *negative* effects relate to greater parental time endowments for lower birth order children, greater devolvement of responsibility to lower birth order children and the simple fact that mothers are older when they have higher than lower birth order children. Those hypotheses predicting *positive* effects of birth order on education are: the growth of family income over the life cycle; the possibility that older siblings may be encouraged to leave school early to assist in providing resources for the younger members of the family; parental child-raising experience that might advantage younger siblings; and finally, the possibility that younger children may benefit from time inputs both from parents and older siblings. Our data suggest that it is the negative effects that dominate in Britain.

6 Conclusions

We used unique retrospective family background data from wave 13 of the British Household Panel Survey to explore the degree to which family size and birth order affect a child’s subsequent educational attainment. There are a number of arguments in the literature suggesting that siblings are unlikely to receive equal shares of the resources devoted by parents to their children’s education. We constructed a composite birth order index that effectively purges family size from birth order and used this to test whether or not siblings are assigned equal shares in the family’s educational resources.[34] We found that sibling shares are decreasing with birth order. Controlling for parental family income, parental age at birth and family level attributes, we found that children from larger families have lower levels of education and that there is an additional negative birth order effect. It is interesting that in contrast to Black et al. (2005), our family size effect did not vanish once we control for birth order, perhaps reflecting different cultural or institutional factors in the two countries. Moreover, our findings were robust to a number of specification checks.

[34] The correlation coefficient between family size and birth order is 0.7047, while the correlation coefficient between family size and our birth order *index* is just 0.0697, as discussed in Section 4.1.

We experimented with endogenising family size in our model of years of education and found that our results about the negative effect of family size and birth order still held. However, there were not natural instruments in our dataset, and it would be desirable to pursue this line of research in future work should better data become available. Fertility is an important research area—especially so given the recent plethora of reports and papers suggesting a coming ‘generational storm’ following declining fertility rates.[35] Our results do have some relevance with regard to fertility debates, as they show unambiguously that on average, children from smaller families achieve higher educational qualifications. To the extent that smaller families increasingly become the norm, this may be associated with a growth in the country’s stock of human capital. And high levels of parental human capital will also—as our estimates show—have an impact on the educational attainment of their children. As it is well known that higher levels of human capital translate into higher growth rates, then lower fertility rates could well be associated with higher per capita GDP growth rates through their impact on educational attainment.

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Appendix

Appendix A: The British educational system

The brief summary below covers England, Wales and Northern Ireland. It was obtained from: http://www.essex.ac.uk/ip/aclife/british.htm British education system (note that the system in Scotland differs slightly).

Education in Britain is compulsory between the ages of 5 and 16 (11 years of schooling). Before 1972, the minimum school leaving age was 15 years, and we have allowed for this when constructing our measure of years of completed schooling. At the age of 16, students wishing to continue academic study take examinations in a number of subjects in the General Certificate of Secondary Education (GCSE). Following GCSE, students take two further years of study,

[35] Conley and Glauber (2005) employ instrumental variable estimation to control for endogenous family size using a sex-mix instrument. We do not have this information in our data. Using 1990 US Census data for children still living in the parental home, they find that children from larger families are less likely to attend private school, more likely to be held back in school, and that there is a birth order effect.

following between two and four subjects (usually three). The number of subjects is small, and the range of disciplines followed is generally narrow. It is common for example to take either all arts-based subjects or all science-based subjects. It is less common to mix them. Each subject is studied to a high level of specialization, and coursework and examinations involve a considerable amount of essay writing. At the end of this 2-year period, students take the examinations for the Advanced level of the General Certificate of Education ('A' levels).

Students in the United Kingdom have therefore normally completed 13 years of full-time education before entering university. This is 1 year more than most US high school students have on entering a US college. Admission to universities in the United Kingdom is competitive, and around 35% of the age group now normally expect to go on to higher education. Universities in Britain are autonomous bodies, empowered under their Charters or other acts of incorporation to award their own degrees. Undergraduate degrees normally take 3 years—1 year less than most Bachelor degree schemes in the United States. Although the two systems are not completely comparable, the following table provides a useful comparison.

Table 13 Comparison of the UK and US education systems

United States	United Kingdom
School grades 1–12 (age 5–17)	School grades 1–11 (age 5–16). At Age 16, GCSE School 'Sixth Form'—2 years
University freshman year	A level at age 18
Sophomore year, Junior year, Senior year and Graduation	University 1st Year, 2nd Year, 3rd Year and Graduation

Appendix B: Variance of birth order index *B*

It is interesting to see if the predicted means and variances of *B* for each family size are similar to what we find in the sample. The following table gives the actual mean and variances of *B* and the predicted variances by family sizes. Note that the predicted means and variances are based on the assumption that all children in each family appear in the data, which does not happen in the sample.

Table 14 Actual mean and variances of *B* and predicted variances by family size

	Actual mean	Actual variance	Predicted variance
Family size=1	1	0	0
Family size=2	0.995	0.111	0.22
Family size=3	0.978	0.168	0.25
Family size=4	0.973	0.200	0.27
Family size=5	1.021	0.223	0.27
Family size=6	1.016	0.241	0.28
Family size=7	1.009	0.303	0.29
Family size=8	1.079	0.243	0.29
Family size=9	1.102	0.302	0.30
Family size=10	1.206	0.252	0.30

Generally, we find that the actual means and variances in our sample are very close to the predicted values. Notice also the actual variances are less than the predicted variances in most cases.

The predicted variances were calculated as follows. The general formula for variance is $\sigma^2 = \frac{\sum (X_i - \overline{X})^2}{N-1}$, where $\overline{X}$ is the mean, and N is the number of scores.

In Section 4.1, we noted that by construction, the mean of birth order index is $\overline{B} = 1$ across and within all family sizes. The variance of B can be obtained by plugging the value of B into the above formula. To illustrate, for example:

$$\sigma^2_{familysize=2} = \frac{(0.67-1)^2 + (1.33-1)^2}{2-1} = 0.22$$

$$\sigma^2_{familysize=3} = \frac{(0.5-1)^2 + (1-1)^2 + (1.5-1)^2}{3-1} = 0.25$$

$$\sigma^2_{familysize=4} = \frac{(0.4-1)^2 + (0.8-1)^2 + (1.2-1)^2 + (1.6-1)^2}{4-1} = 0.27$$

$$\sigma^2_{familysize=5} = \frac{(0.33-1)^2 + (0.67-1)^2 + (1-1)^2 + (1.33-1)^2 + (1.67-1)^2}{5-1} = 0.27$$

Repeat this exercise for all the family sizes (up to ten) in our sample; the rest of the variances of B can be summarised as follows:

$$\sigma^2_{familysize=6} = 0.28$$

$$\sigma^2_{familysize=7} = 0.29$$

$$\sigma^2_{familysize=8} = 0.29$$

$$\sigma^2_{familysize=9} = 0.30$$

$$\sigma^2_{familysize=10} = 0.30$$

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