# Sibling spacing effects across the birth order

Preliminary draft – do not cite

Marie Husøy Sæther

Norwegian University of Science and Technology,

Department of Economics, Dragvoll, N-7491 Trondheim, Norway

E-mail: marie.h.sather@ntnu.no

# Sibling spacing effects across the birth order

## Abstract

This paper adds to the small literature investigating sibling spacing effects on school outcomes. I find negative spacing effects for students of birth order one. This is contrasting to the existing empirical literature, though coincides with the observed performance gap between first-borns and only children. The paper demonstrates the importance of allowing for separate effects for distinct birth orders: Spacing effects vary in magnitude, significance and sign across birth orders. This suggests that effects estimated without such flexibility in the empirical approach might seem non-existing or appear with the wrong sign, depending on the birth order composition in the sample.

Keywords: sibling spacing, birth order effects, student performance

JEL codes: I20, J13

Sibling spacing effects across the birth order

## Introduction

The present paper adds to the small empirical literature investigating sibling spacing effects on school outcomes. This paper is motivated by two findings from the existing literature on the relationships between family characteristics and student performance. First, pioneer work in the birth order literature states that the only child performs worse than the firstborn child with younger siblings (Zajonc and Markus, 1975; Zajonc, Markus and Markus, 1979). This is confirmed in recent empirical studies (Kristensen and Bjerkedal, 2010; Härkönen, 2014; Mogstad and Wiswall, 2016). Secondly, empirical studies on sibling spacing effects provide evidence that the first-born child with siblings, benefits from a larger space down to his siblings (Price, 2008; Buckles and Munnich, 2012). Thinking of an only child as a first born child with infinite space to the second born sibling, the findings from the latter literature potentially imply that the only child should be better off than any first born child with a finite space to siblings. Thus, the existing evidence from the two literatures is somewhat inconsistent. Recent empirical studies of sibling effects devote little or no attention to comparing outcomes of children with siblings to outcomes of only children.

A negative relation between birth order and outcomes such as academic performance, IQ and adult income is well documented (Behrman and Taubman, 1986; Black, Devereux and Salvanes, 2005; Bjerkedal et al., 2007; Iacovou, 2008; Kristensen and Bjerkedal, 2010; Bonesrønning and Massih, 2011; Härkönen, 2014). But researchers have yet to conclude which mechanisms cause this pattern. One of the most influential theories, the Sibling tutoring hypothesis, builds on the stylized fact of a performance gap between students of birth order one, with and without younger siblings. In recent empirical studies, sibling effects (i.e. birth order and spacing effects) are identified through instrument variables, e.g. sibship sex compositions, multiple births and pregnancy abortions. However, these studies make conclusions from samples of students that are poorly suited for comparing with the only child. Hence, much existing empirical evidence is not appropriate for evaluating the Sibling tutoring hypothesis. The two child family is a relevant study in this case: Variations in spacing between the siblings create observations of students of birth order one that have more or less in common with the only child.

The present paper put the existing evidence about spacing effects under scrutiny. I use rich administrative data from Norway, and investigate spacing effects on student performance within families with two and three siblings, while also separating between spacing effects for first born, second born and third born siblings. This approach; which is more flexible than the most common approaches in the existing literature, falls short of addressing the endogeneity of the spacing variable. However, in exploring some possible channels of selection bias, I argue that the estimates are quite reliable.

The basic finding is that first born and second born students benefit from being close in age, whereas among third born students a longer interval up to the second born is associated with a better performance. This is in accordance with the performance pattern of only children discussed above, and can be interpreted into Robert Zajonc's Sibling tutoring hypothesis. To my knowledge this finding is quite unique in the empirical spacing literature[1].

Importantly, the estimated effect of spacing for academic achievement between two subsequent siblings vary across the birth order. In particular, first born children benefit from a short downwards age interval, while no such effect is found for students of birth order two; and the second born benefit from a short upwards age interval, while students of birth order two benefit from a longer upwards interval. This demonstrates the importance of accounting for the distinct birth order.

## Literature

### Empirical studies

The empirical literature on the relation between sibship age differences and children's academic outcomes is small[2]. Many studies estimate effects of sibship size and birth order; however, much fewer have addressed the question of timing of births. This is despite the fact that the main variation across families with children in developed countries lies in the timing of births rather than in sibship size.

The basic conclusion is that longer sibling age gaps are associated with better outcomes. Stafford (1987) finds a negative effect on school performance for boy siblings in nearby age ranges. Powell and Steelman (1990) and Powell and Steelman (1993) find that sibling age closeness has a negative effect on schooling outcomes. Hayes, Luchok, Martin, McKeown and Evans (2006) find that sibling age spacing is a predictor of school readiness

---

[1] Bjerkedal et al. (2007) find indications of a similar pattern in their analysis.
[2] Empirical studies that have looked at effects of sibling spacing have focused primarily on infant birth weight and mortality, mother's health and mother's labor market outcomes.

(measured by the Cognitive Skills Assessment Battery), where siblings born less than 24 months apart are more likely to fail the test.

The main empirical difficulty is accounting for selection into sibling spacing. Parents have great influence on the age intervals between their children, can often choose their preferred timing of births, and update their preferences when they observe characteristics of already born children (Rosenzweig, 1986). Estimation techniques that fail to account for this produce biased estimates. This includes the above studies. Buckles and Munnich (2012) use an instrumental variable strategy exploiting exogenous variation in sibling spacing driven by miscarriages to solve this. They find evidence of better academic performance among older siblings when the spacing increases, (specifically, an increase in test scores of 0.17 standard deviations when the downward spacing interval increases with one year), though no effect of spacing for the younger, and show that OLS estimations underestimate the benefit of spacing in their sample.

Findings in existing studies are explained by various factors such as income effects and mechanisms proposed by theories of birth order differences. Even though discussions from the birth order literature are included as references, none of the studies apply an estimation strategy that allows for distinct effects across the birth order. Buckles and Munnich (2012) estimate separate effects for pairs of subsequent siblings from a sibship; however, not for each birth order or sibship size.

**Theories of birth order effects and sibling spacing**

Many empirical studies have reported evidence of a negative relation between birth order and children's school outcomes in developed countries, where first born children outperform their younger siblings (Black, Devereaux and Salvanes, 2005; Iacovou, 2008; Bonesrønning and Massih, 2011). Beyond agreeing on the trend of outcomes across the sibship, researchers have shown interest for exploring the mechanisms behind the observed pattern. Some suggest that siblings have different potentials from birth; others turn to the significance of family dynamics, such as parent-child and sibling-sibling interactions. If such interactions are of importance, it is not hard to imagine that birth order effects might be influenced by age differences within the sibship. The same is thought to be true for distributions of parental resources.

The literature on birth order and family size effects have recognized the relevance of spacing patterns for their conclusions. Black et al. (2010) suggest that effects of family size differ between families with different intra sibship spacing patterns. Furthermore, a few empirical studies of birth order effects have included spacing variables in their analyses; however, their conclusions are not in agreement. Price (2008) conclude that birth order effects increase with longer space; Bjerkedal et al. (2007) claim that birth order differences are smaller when spacing increases; de Haan (2010) finds no effect of spacing on birth order.

The most influential theories of birth order effects are the Resource dilution hypothesis and the Confluence model, the latter extended with the Sibling tutoring hypothesis. They offer slightly contrasting predictions of effects of spacing on birth order differences.

First, the Resource dilution hypothesis (Hanushek, 1992; Price 2008; Hotz and Pantano, 2015) argues that decreasing performance over the sibship is induced by variations in parental investment. The amount of parental resources available to each child, e.g. parent-child quality time, money or child monitoring, dilutes as the sibship grows. Hence, depending on birth order, children are allocated different amounts of childhood investment as they experience different time patterns of family compositions. This variation is reflected in children's academic performance. First born children receive more from their parents, since they are only children for some years until the next sibling is born. Consequently, the oldest sibling does on average obtain better outcomes. A longer age gap between siblings extends the time the oldest is an only child, and predicts better outcomes for the first born. The analysis of a parent-child quality time version of the Resource dilution hypothesis in Price (2008) suggests falling outcomes for higher birth orders as the upward interval increases.

Hence, in the Resource dilution framework large spacing is beneficial for children of birth order one, whereas younger siblings benefit from age closeness to the oldest.

Secondly, the Confluence model attributes birth order effects to deteriorations of the average intelligence level in the family induced by the birth of additional siblings (Zajonc, 1975; Zajonc and Markus, 1975; Zajonc, 1976). The first born child lives his first years in a high quality environment interacting with mature adults. As siblings are born, the average intelligence level in the family falls, and the children are brought up in a less stimulating home environment. As a result, birth order effects arise.

In this framework, age differences play an important role. First, downward spacing determines how long the first born lives in the high quality environment. Secondly, having siblings might be an asset for the younger if the oldest are mature enough to act as ‘substitute’ parents, possibly offsetting or reversing negative birth order effects. This means that the last born could be raised in a more mature family environment than for instance the second born. The spacing effect for younger siblings appears to be an empirical question.

In addition to negative birth order effects, there is evidence that only children perform worse than children of low birth orders who have younger siblings. To embody that growing up with siblings seems to give an advantage Zajonc extended his model with the Sibling tutoring hypothesis (Zajonc and Markus, 1975; Zajonc, Markus and Markus, 1979): Older siblings benefit from teaching the younger. The theoretical prediction of how sibling spacing affects this mechanism is not clear: sibling interaction might be more frequent among siblings who are close in age, but the quality of inter sibling teaching and learning might be better with a longer age gap. For instance, Cicerelli (1973) suggests that the receptiveness of younger siblings to being taught by older might increase with the age difference.

Table 1 summarizes the predictions of spacing effects from the birth order theories.

Insert table 1 here.

**Data and summary statistics**

The data is register data from Statistics Norway. It includes information about school performance and family background characteristics of students in the Norwegian elementary and lower secondary school from five subsequent cohorts of $5^{th}$ and 8th graders from 2007-2011, and two subsequent cohorts of 9th graders from 2010-2011.

School performance is measured by scores on national tests in reading and mathematics. The same test is distributed to all Norwegian schools, public and private. This means that all students in a cohort face the same questions. Students receiving special education or special language tuition (Norwegian tuition) can apply to be exempted from taking the test; however, participation is usually high. There is usually a strong correlation between student performance on national tests and GPA from lower secondary school.

Sibling spacing is measured as the number of years between two siblings in a family. Year of birth is deduced from information about when the students attended 5th, 8th and/or 9th grade tests. The data do not include register information about year and month of birth for the students; however, since it is only exceptional that children start school early and grade retention because of poor academic achievement is not practiced in Norway, records of test participation are very good indicators of age and year of birth. Birth order and sibship size are given in the register data. Birth order is defined as the student's rank among the children of the student's mother. Sibship size equals the total number of children in the household of the student at the time of the test. Siblings are indicated in the data by a unique family identification number.

Finally, the data includes background information. Specifically, student gender and immigrant status; parental work income (in NOK 10,000), educational attainment and age; and family structure, indicating family intactness, presence of a step parent in the household and single parenthood.

The data contains 598 029 observations of student test performance. First, I restrict the sample to individuals from two and three child families with some records of test performance of all of the siblings in the sibship. This is to ensure that the measures of birth order, sibship size and sibling age intervals in the sample are as correct as possible (sibship age intervals are deduced from information about the timing of test attendance for the siblings). Next, I eliminate families with twins or triplets from the sample (1-2% of births in Norway each year are multiple births). In the case of multiple births, the recorded student birth order is shifted. E.g. when twins are born, they are both assigned the same birth order, which is often shifted up. For instance, a three child family consisting of a singleton and a pair of twins has the birth orders 1+3+3, even though only two births have occurred. This might influence the regression results since I estimate spacing effects conditional on birth order. Finally, to be able to estimate sibship size specific spacing effects, I exclude students from families that change sibship size during the observation period.

The final sample consists of 70 976 students from two child families, (35 488 from each birth order), and 17 520 students from three child families, (5 840 from each birth order). The summary statistics in table 2 indicate that the average age interval between two subsequent siblings is 2-3 years, and somewhat smaller in three child families than in two child families. In table 2 each student counts as one observation. In the regressions, the number of observations of test performance associated with each student varies. Some students have participated on three tests during the years 2007-2011, some on two, and some on only one.

Table 3 presents raw scores on the tests for first born students, with and without siblings. On average, students with siblings perform better than only children, and their performance seems to weaken as the age interval down to the second born increases; that is, as they become more similar to the only child. No conclusions can be made from the descriptive statistics since background characteristics are not accounted for.

Insert tables 2 and 3 here.

**Empirical approach**

The outcome variable is score on national tests in reading and mathematics for 5th, 8th and 9th graders. To facilitate the comparison of performance across grades and subjects, the test scores are standardized for each cohort and subject with mean equal to zero and standard deviation equal to one. The standardization was carried out before the adjustments to the sample were made. For the specification given by equation (1), test performances from all three grades are pooled.

$$Testscore_{ijgt} = \alpha_{\iota} Years_{ij} + X_i'\delta + Y_j'\gamma + d_t + \epsilon_{ijgt} \qquad (1)$$

$Testscore_{ijgt}$ is score on the national test in reading or mathematics of student $i$ from household $j$ in grade $g$ at time $t$. $Years_{ij}$ is the number of years between student $i$ and his sibling(s), with $\alpha_{\iota}$ as the coefficient of interest. $X$ and $Y$ are vectors of student and family characteristics including student gender and immigrant status; parental income, educational attainment and age; and a dummy indicating family intactness (the student's biological parents both live in the household). $d_t$represents year dummies. $\epsilon_{ijgt}$is the error term. In the regression for a student in a two child family, one $Years$-variable is included in the regression, counting the years between the first and second born child. In regressions for students from three child families two $Years$-variables are included, giving the distance between the first and second, first and third, or second and third born siblings, depending on the birth order of the student. Equation (1) is estimated separately for each birth order (1-3) to allow for different effects of sibling spacing across the birth order. Moreover, the empirical birth order literature routinely controls for selection into sibship size. Families who choose to have many children are most likely not comparable to families with preferences for a smaller sibship. Since children with high birth orders are observed in larger families only, it could be that the correlation between family size and child outcomes is misinterpreted as birth order effects. Here, this is handled by estimating the equation for each sibship size (2 and 3) separately.

Buckles and Munnich (2012) argue that OLS underestimates the benefit of spacing in their sample due to selection bias. Parental preferences for family life and activities, the quality of the parents’ relationship, characteristics of already born children, and mother’s labour market attachment or enrolment in college/university are some influences to the timing of pregnancies. To investigate the degree of selection into spacing in my sample, I regress spacing between the first and second born child on observed characteristics of parents and the first born child in the family. Equation (2) is estimated for each sibship size.

$$Years_{1-2j} = X_1'\delta + Y_j'\gamma + d_t + \epsilon_{ij} \quad (2)$$

$Years_{1-2j}$ is the number of years between the first and second born in family $j$, $X_1$ represent characteristics of the first born child, and $Y_j$ represent parental characteristics. The results are included in table 4.

As a second assessment of selection, equation (1) is estimated with controls added one for one to see how sensitive the estimated spacing effect is to controlling for different background characteristics. These results are commented in the results section.

Insert table 4 here.

The results indicate some selection into sibling spacing. First, in both sibship sizes family intactness is associated with longer age intervals within the sibship. Buckles and Munnich (2012) report shorter spacing if the mother is married at the first birth. Second, Buckles and Munnich (2012) find that spacing increases with the mother's level of education. My results for three child families coincides with this; however, in two child families I find that a higher level of mother's education is associated with shorter age intervals. This suggests selection bias of opposite signs in the two sibship sizes. Failing to control for such selection into spacing will result in underestimating the benefit of spacing in two child families, whereas overestimating the benefit of spacing in three child families. Importantly, this demonstrates the importance of controlling for sibship size in estimating spacing effects. Regrettably, I am not able to conclude about selection on unobservables, but the insights about selection from observed characteristics could indicate a pattern for unobservables.

Finally, I investigate the degree of selection by estimating spacing effects in a sub-sample of intact families (i.e. families with both biological parents in the household). Family intactness could be an indicator of unobservable parental characteristics such as the quality of parental relationships or time spent at home by the parents. Estimating equation (1) for a sub-sample from intact families did not give results much different from those obtained from the full sample.

**Results**

The results from estimating equation (1) are presented in tables 5 and 7. Sibship age intervals matter for school performance. The birth order literature has established that the average first born outperforms his younger siblings. Birth order effects estimated on students from the data in the present paper suggest that first born students on average perform 10-20% of a standard deviation better than second born students, depending on subject and sibship size. This effect is of similar size as in recent influential studies on birth order effects on education related outcomes[3].

The results suggest that the benefit of being first born is partially offset when the age interval to the next sibling increases: In two child families an increase in age gap of one year is associated with a drop in performance of the first born by about 2-3% of a standard deviation. In three child families the drop is about 5% of a standard deviation. This finding is quite unique in the spacing literature.

Also the second born benefit of age closeness between the first two siblings in the sibship (in mathematics). The third born sibling in a sibship of three benefits from a longer age interval up to the second born. The effect of one additional year between the second and third born is estimated to be 5-6% of a standard deviation.

Importantly, the estimated effect of upwards or downwards spacing between two subsequent siblings for academic achievement varies in magnitude, significance and sign, across birth orders. In particular, the first born child benefit from a short interval down to the subsequent sibling, whereas there is no significant effect of downward spacing for the second born child (in three child families); and a short interval upwards is associated with better performance for the second born child, whereas the better performance among third born students is found where the interval upwards is long.

This demonstrates the importance of accounting for birth order when estimating spacing effects. Estimating separate effects for the old and young of two subsequent siblings might not be sufficient for getting reliable estimates: Effects estimated without birth order controls might seem non-existing or appear with the wrong sign, depending on the composition of birth orders in the sample. Furthermore, controlling for sibship size is important. The results from table 4 indicate that selection bias goes in opposite directions in families with two and three children.

[3] E.g. 14% of a standard deviation is found in Bjerkedal et al. (2007); 7-8% in Iacovou (2008); 17% i Black et al. (2005).

The specification given by equation (1), assumes a linear effect of sibling spacing. The results from estimating the model with dummies for distinct space intervals are reported in tables 6 and 8. The linearity assumption seems not to be very wrong for the effect of downward spacing for students of birth order one, especially in mathematics in two child families and reading in three child families. The same applies to the effect of upward spacing for students of birth order three. On the contrary, the estimates for the second born show that the linearity assumption is far from correct for this birth order. The first results (tables 5 and 7) show no significant effect in reading, but a significant negative effect of upward spacing for the second born in mathematics. However, the dummy variable coefficients suggest a positive effect of spacing for reading skills in two child families, and a declining benefit of spacing in mathematics, that becomes negative as the age interval becomes longer than five years. The negative effect of upward spacing in mathematics in three child families is no longer significant.

Insert tables 5-8 here.

Buckles and Munnich (2012) estimate a positive effect of spacing for the older of two subsequent siblings, and no effect for the younger, and demonstrate that applying OLS underestimates the benefit of spacing in their sample. The basic conclusions in the present paper suggest an opposite pattern. Finding negative spacing effects for the first born might be a result of bias in the OLS estimates, where families that perform better select into shorter spacing. The results from regressing spacing on background characteristics suggest that this might be relevant in two child families. Higher educational attainment of the mother is associated with shorter spacing. However, in three child families an increase in the mother's level of education is associated with longer spacing. This suggest that selection bias would cause an overestimation of the benefit of spacing, if selection on unobserved characteristics goes in the same direction. Hence, the negative spacing effects found for students of birth order one in three child families might actually be underestimated. Also, finding larger coefficients in three child families compared with two child families strengthens this result.

Tables A3 and A4 in the appendix show how sensitive the estimated spacing effects for first and second born students are to controlling for various background characteristics. Failing to account for parental education produces too large negative spacing effects in two child families, and too small negative effects in three child families.

Selection into spacing goes in opposite directions in two and three child families. To explore this pattern, I re-estimate tables 5-8, for sub-samples of students, indicated by different levels of mother's educational attainment. The sub-samples are students of mother's with education at the college, university or PhD level; at the high school level; and with lower secondary school (compulsory education). The results are reported in tables 9-14.

Moreover, empirical studies of birth order effects have found smaller differences between birth orders in families with low educated parents compared with families with high educated parents (Bjerkedal et al., 2007; Booth and Kee, 2009; Bonesrønning and Massih, 2011). This might indicate that also spacing effects differ across parental education levels, since spacing are believed to influence birth order effects (Bjerkedal et al., 2007; Price, 2008).

Insert tables 9-14 here.

Looking at two child families, the benefit of age closeness for students of birth order one is found in families with parental education up to high school. Among the families with parental education at the college or university level, there is no significant effect of spacing on school performance for the oldest sibling, except for the case of a two-year interval and a seven-year interval. The two-year interval seems not to have a significant effect in families with less education.

This pattern is reversed in tree child families. The negative effect of spacing (down to the subsequent sibling) for the oldest sibling is found among students from families where the mother has been enrolled in college or university. Especially, there is a drop in performance when the interval exceeds three years. This subgroup of first born students also has a significant positive effect of spacing down to the third born sibling. The positive effect of upwards spacing for the third born child is found in families where the mother has education above the compulsory level.

## Spacing effects and birth order theories

Despite convincing evidence of the existence of birth order effects, which mechanisms are generating the observed pattern remains unsettled. It is obviously hard to discriminate between different theories from empirical findings, since theories might predict similar patterns, supplement each other rather than being competing or mutually exclusive, and each point to some of the relevant factors. However, insights about effects of sibling spacing might provide evidence for some of the mechanisms outlined in theories, even if complete theories cannot be proved (or refuted).

The general conclusion in spacing studies is that the oldest sibling benefit from a longer age interval down to younger sibling(s). This is in line with predictions from the Resource dilution hypothesis and the Confluence theory. However, this conclusion does not correspond well with the evidence that only children perform worse than other children of birth order one with siblings, if thinking of only children as having an infinite gap down to potential siblings. The first born with siblings has more in common with the only child when the interval down to the subsequent sibling increases, since their early childhoods are more similar. This predicts that we should expect outcomes to worsen as the gap between the first and second born becomes large. This is confirmed in the present study. To my knowledge only one other empirical study has presented evidence of this pattern (Bjerkedal et al., 2007). The finding is consistent with mechanisms presented in the Sibling tutoring hypothesis, if assuming that teaching and learning interactions are more prevalent among siblings of similar age.

Failing to document such negative effects of large spacing might be explained by selection into family size. Individuals from only child families are different from those from larger sibships, and would perform at a lower level even if they would have grown up in a larger family. Alternatively, it might be that samples used in existing studies have too short intervals between the siblings. Long gaps could be beneficial up to a certain point, where the returns to undivided parental investment or home stimuli reduces, and the positive sibling tutoring effect becomes important. This shift in mechanisms at work might show in a sample with very long intervals.

A better performance of the last born of three child families in families with a longer interval up to the second sibling also fits with the Sibling tutoring hypothesis, if believing that the receptiveness of younger siblings to being taught by older might increase with the age difference (Cicerelli, 1973). Alternatively, this could be taken as evidence of the theory outlined in the Confluence model: Younger siblings benefit from having a more mature home environment with siblings who are some years older.

## Gender effects

To my knowledge, no recent studies have estimated gender-specific spacing effects. Given the data, it is possible to investigate whether sibling spacing matters differently for boys and girls. First, I add an interaction term between $Years$ and a dummy indicating male student to equation (1). There seems to be little systematic difference in the effects of spacing between boys and girls: The interaction term is significant for some combinations of subject, birth order and sibship size only, and in many cases only at the 10% level. However, the estimates that are significant, suggest that boys benefit more from a larger age difference than girls. The tables reporting the results (A5 and A6) are enclosed in the appendix.

Furthermore, there is reason to expect that some of the underlying mechanisms described in birth order theories might depend on the sex composition of the sibship: For instance, the degree of sibling interaction. The main results in the present study suggest that the oldest sibling benefit from having younger siblings in nearby ages, possibly through a tutoring effect. I re-estimate equation (1) for sub-samples of all-girls and all-boys sibships, to see if this effect is magnified in same-sex sibships. The results are summarized in tables 15-16. I find a large significant negative effect of increased spacing on outcomes for birth order one students from all-boys three child families, compared with students from mixed sibships and all-girls families. It seems that age differences are particularly important for student outcomes in all-boys families (possibly due to sibling interactions). This finding is contrasting to the evidence presented in Stafford (1987), where a negative effect of sibling age closeness is found on school performance among boys.

Insert tables 15 and 16 here.

## Conclusion

There is little empirical evidence on the effects of sibling spacing for school outcomes in the Western world. This is despite the fact that spacing is an important source of variation in sibship characteristics, and that empirical literature on effects of family size and birth order recognize that spacing patterns matter for their conclusions. Furthermore, investigating spacing effects might help differentiating between theories of birth order effects.

Most studies report a positive effect of spacing for the oldest sibling. This is a finding that coincides well with predictions from the birth order theories, such as the Resource dilution hypothesis and the Confluence model. However, the observed performance gap between students of birth order one with and without siblings is less compatible with these results. Thinking of an only child as a first born with infinite spacing down to his siblings implies that the effect of spacing should (at some point) become negative.

The present study estimates negative effects of spacing for students of birth order one. This finding is relatively unique in the empirical spacing literature and fits well with the stylized fact about the performance of only children compared with first born children with siblings. A benefit of (upward) spacing is found for students of birth order three in three child families.

Importantly, the present analysis demonstrates the importance of controlling for birth order and sibship size when estimating spacing effects. The benefit of upwards or downwards spacing between two subsequent siblings varies in magnitude, significance, and even sign, across birth orders. This suggests that effects estimated without this kind of flexibility in the empirical approach might seem non-existing or appear with the wrong sign, depending on the composition of birth orders in the sample.

Ultimately, the main empirical challenge in estimating spacing effects is to find an exogenous source of variation in sibling age intervals; that is to eliminate selection bias. Although the present paper does not have the appropriate data for this, in exploring some possible channels of selection bias, I argue that the estimates are quite reliable.

Still, there is need for further studies on the effects of sibling spacing. Specifically, studies that combine an empirical strategy that eliminates selection bias, while estimating distinct effects across the birth order and sibship sizes. Moreover, in exploring the relevance of the Sibling tutoring hypothesis further, studies with data of children from two child families with large variation in sibling spacing, including very long intervals, might help reach conclusions.

References

Behrman, J.R. and Taubman, P. (1986): Birth Order, Schooling and Earnings. *Journal of Labor Economics, 4 (3), part 2*, S121-S145.

Bjerkedal, T., Kristensen, P., Skjeret, G. A. and Brevik, J. I. (2007). Intelligence Test Scores and Birth order among Young Norwegian Men (Conscripts) Analyzed within and between Families. *Intelligence, 35,* 503-514.

Black, S. E., Devereaux, P. J. and Salvanes, K. G. (2005). The More the Merrier? The Effect of Family Size and Birth Order on Children's Education. *The Quarterly Journal of Economics 120(2),* 669-700.

Black, S. E., Devereaux, P. J. and Salvanes, K.G. (2010): Small family, smart family?: Family size and the IQ scores of young men. *The Journal of Human Resources, 45(1),* 33-58.

Bonesrønning, H. and Massih, S. S. (2011). Birth Order Effects on Young Students' Academic Achievement. *The Journal of Socio-Economics 40,* 824-832.

Booth, A. L. and Kee, H. J. (2009). Birth Order Matters: The Effect of Family Size and Birth Order on Educational Attainment. *Journal of Population Economics 22,* 367-397.

Buckles, K. S. and Munnich, E. L. (2012). Birth Spacing and Sibling Outcomes. *The Journal of Human Resources 47/3),* 613-642.

Cicerelli, V. G. (1973). Effects of Sibling Structure and Interaction on Children's Categorization Style. *Developmental Psychology 9(1),* 132-139.

De Haan, M. (2010): Birth order, family size and educational attainment. *Economics of Education Review, 29,* 576-588.

Hanushek, E. A. (1992). The Trade-Off between Child Quantity and Quality. *Journal of Political Economy 100(1),* 84-117.

Härkönen, J. (2014). Birth order effects on educational attainment and educational transitions in West Germany. *European Sociological Review, 30(2),* 166-179.

Hayes, H., Luchok, K., Martin, A., McKeown, R. and Evans, A. (2006). Short Birth Intervals and the Risk of School Unreadiness among a Medicaid Population in South Carolina. *Child: Care, Health & Development 32(4),* 423-430.

Hotz, V.J. and Pantano, J. (2015): Strategic parenting, birth order, and school performance. *Journal of Population Economics, 28*, 911.936.

Iacovou, M. (2008). Family Size, Birth Order and Educational Attainment. *Marriage and Family Review 42(3),* 35-57.

Kristensen, P. and Bjerkedal, T. (2010). Education attainment of 25 year old Norwegians according to birth order and gender. *Intelligence, 38,* 123-136.

Mogstad, M. and Wiswall, M. (2016): Testing the quantity-quality model of fertility: Estimation using unrestricted family size models. *Quantitative Economics, 7,* 157-192.

Powell, B. and Steelman, L. C. (1990). Beyond Sibship Size: Sibling Density, Sex Composition, and Educational Outcomes. *Social Forces 69(1),* 181-206.

Powell, B. and Steelman, L. C. (1993). The Educational Benefits of Being Spaced Out: Sibship Density and Educational Progress. *American Sociological Review 58(3),* 367-381.

Price, J. (2008). Parent-Child Quality Time. Does Birth Order Matter? *The Journal of Human Resources 43(1),* 240-265.

Rosenzweig, M.R. (1986): Birth spacing and sibling inequality: Asymmetric information within the family. *International Economic Review, 27(1),* 55-76.

Stafford, F. P. (1987). Women's Work, Sibling Competition, and Children's School Performance. *American Economic Review 77(5),* 972-980.

Zajonc, R. (1976). Family Configuration and Intelligence. *Science 192,* 227-236.

Zajonc, R. and Markus, G. B. (1975). Birth Order and Intellectual Development. *Psychological Review 82(1),* 74-88.

Zajonc, R., Markus, H. and Markus, G. B. (1979). The Birth Order Puzzle. *Journal of Personality and Social Psychology 37(8),* 1325-1341.

Zajonc, R. (1975). Birth Order and Intelligence: Dumber by the Dozen. *Psychology Today 8,* 37-43.

## Appendix

Table A1. Summary statistics: # years between siblings

**Two child families**

# years between sibling…
1 and 2

| | #families | % |
|---|---|---|
| 1 | 2 718 | 7.60% |
| 2 | 11 662 | 32.86% |
| 3 | 11 757 | 33.13% |
| 4 | 6 004 | 16.92% |
| 5 | 2 229 | 6.28% |
| 6 | 890 | 2.51% |
| 7 | 228 | 0.64% |
| ∑ | 35 448 | 100% |

**Three child families**

# years between sibling…

| | 1 and 2 | | | 1 and 3 | | | 2 and 3 | |
|---|---|---|---|---|---|---|---|---|
| | #families | % | | #families | % | | #families | % |
| 1 | 871 | 14.91% | 1 | - | - | 1 | 631 | 10.80% |
| 2 | 2 945 | 50.43% | 2 | 33 | 0.57% | 2 | 2 074 | 35.51% |
| 3 | 1 537 | 26.32% | 3 | 470 | 8.05% | 3 | 1 813 | 31.04% |
| 4 | 392 | 6.71% | 4 | 1 477 | 25.29% | 4 | 989 | 16.93% |
| 5 | 88 | 1.51% | 5 | 1 838 | 31.47% | 5 | 302 | 5.17% |
| 6 | 7 | 0.12% | 6 | 1 436 | 24.59% | 6 | 31 | 0.53% |
| 7 | - | - | 7 | 586 | 10.03% | 7 | - | - |
| ∑ | 5 840 | 100% | ∑ | 5 840 | 100% | ∑ | 5 840 | 100% |

Table A2. Summary statistics: Family characteristics in two and three child families

| | Two child families | Three child families |
|---|---|---|
| Father's educational attainment | 4.60 | 4.88 |
| Mother's educational attainment | 4.76 | 4.96 |
| Father's work income (in NOK 10,000) | 56.39 | 60.66 |
| Mother's work income (in NOK 10,000) | 34.16 | 32.29 |
| Father's age | 43.12 | 43.27 |
| Mother's age | 40.84 | 40.90 |
| Family intactness | 0.80 | 0.88 |
| First generation immigrant | 0.007 | 0.010 |
| Second generation immigrant | 0.028 | 0.035 |

*Note.* Educational attainment at level 4 corresponds to high school graduation. Family intactness is a dummy variable indicating presence of both biological parents in the household, immigrant status is a dummy variable taking the value 1 for first or second generation immigrants.

Table A3. Dependent variable: Test performance. Two child families.
Estimated effects of number of years between the 1st and 2nd born child.
Controls added one for one.

| | 1st born child | | 2nd born child | |
|---|---|---|---|---|
| | *Read* | *Math* | *Read* | *Math* |
| *# years between 1 and 2* | | | | |
| *Control variables* | | | | |
| Non | -0.024** | -0.038** | 0.002 | -0.030** |
| + Male | -0.024** | -0.038** | 0.002 | -0.030** |
| + Intact family | -0.028** | -0.043** | -0.001 | -0.034** |
| + Parental age | -0.017** | -0.033** | -0.005 | -0.037** |
| + Parental educational attainment | -0.012** | -0.027** | 0.005 | -0.027** |
| + Parental work income | -0.012** | -0.028** | 0.004 | -0.028** |
| + Immigrant status | -0.012** | -0.028** | 0.004 | -0.028** |
| + Time dummies | -0.012** | -0.030** | 0.006 | -0.026** |
| # student test observations | 57 317 | 57 317 | 51 424 | 51 424 |

*Note.* Estimates in the last row (with all controls and time dummies included) correspond to the estimates in table 4. **: $p<0.01$, *: $p<0.05$, +: $p<0.10$.

Table A4. Dependent variable: Test performance. Three child families.
Estimated effects of number of years between the 1st and 2nd born child.
Controls added one for one.

| | 1st born child | | 2nd born child | |
|---|---|---|---|---|
| | *Read* | *Math* | *Read* | *Math* |
| *# years between 1 and 2* | | | | |
| *Control variables* | | | | |
| Non | -0.052** | -0.053** | 0.015 | -0.018 |
| + Male | -0.051** | -0.054** | 0.015 | -0.018 |
| + Intact family | -0.049** | -0.051** | 0.013 | -0.021+ |
| + Parental age | -0.036** | -0.037** | 0.009 | -0.024* |
| + Parental educational attainment | -0.046** | -0.047** | 0.004 | -0.028** |
| + Parental work income | -0.046** | -0.047** | 0.003 | -0.030** |
| + Immigrant status | -0.048** | -0.050** | -0.000 | -0.033** |
| + Time dummies | -0.048** | -0.050** | -0.001 | -0.033** |
| # student test observations | 7 726 | 7 726 | 11 614 | 11 614 |

*Note.* Estimates in the last row (with all controls and time dummies included) correspond to the estimates in table 6. **: p<0.01, *: p<0.05, +: p<0.10.

Table A5. Regression: Dependent variable: Test performance. Two child families. Gender effects.

| | 1st born child | | 2nd born child | |
|---|---|---|---|---|
| | Read | Math | Read | Math |
| # years between 1 and 2 | -0.015** | -0.025** | -0.007 | -0.027** |
| | (0.005) | (0.005) | (0.005) | (0.005) |
| # years between 1 and 2 × Male | 0.001 | -0.009 | 0.026** | 0.002 |
| | (0.007) | (0.007) | (0.007) | (0.007) |
| Male | -0.259** | 0.158** | -0.273** | 0.159** |
| | (0.020) | (0.021) | (0.021) | (0.022) |
| $R^2$ | 0.1506 | 0.1369 | 0.1130 | 0.1074 |
| *# student test observations* | 57 317 | 57 317 | 51 424 | 51 424 |

*Note.* Controls and time dummies are included. Standard errors in parentheses. **: p<0.01, *: p<0.05, +: p<0.10.

Table A6. Regression: Dependent variable: Test performance. Three child families. Gender effects

| | 1st born child | | 2nd born child | | 3rd born child | |
|---|---|---|---|---|---|---|
| | Read | Math | Read | Math | Read | Math |
| # years between 1 and 2 | -0.036+ | -0.024 | -0.007 | -0.028+ | | |
| | (0.019) | (0.020) | (0.016) | (0.016) | | |
| # years between 1 and 2 × Male | -0.024 | -0.049+ | 0.012 | -0.009 | | |
| | (0.026) | (0.027) | (0.021) | (0.022) | | |
| # years between 1 and 3 | -0.006 | -0.013 | | | -0.020 | -0.001 |
| | (0.015) | (0.015) | | | (0.020) | (0.021) |
| # years between 1 and 3 × Male | 0.033+ | 0.044* | | | -0.001 | -0.064* |
| | (0.019) | (0.020) | | | (0.028) | (0.028) |
| # years between 2 and 3 | | | -0.001 | -0.002 | 0.071** | 0.061** |
| | | | (0.012) | (0.012) | (0.021) | (0.022) |
| # years between 2 and 3 × Male | | | -0.015 | -0.008 | -0.026 | -0.013 |
| | | | (0.016) | (0.017) | (0.030) | (0.030) |
| Male | -0.338** | 0.044 | -0.178* | 0.239** | -0.090 | 0.502** |
| | (0.084) | (0.088) | (0.077) | (0.078) | (0.099) | (0.100) |
| $R^2$ | 0.1845 | 0.1673 | 0.1571 | 0.1469 | 0.1184 | 0.1154 |
| # student test observations | 7 726 | 7 726 | 11 614 | 11 614 | 6 410 | 6 410 |

*Note.* Controls and time dummies are included. Standard errors in parentheses. **: p<0.01, *: p<0.05, +: p<0.10.

**Tables**

Table 1. Birth order effect theories and predictions of sibling spacing effects

| Theory | Predictions of sibling spacing | |
|---|---|---|
| | 1st born sibling | Later born sibling(s) |
| Resource dilution hyp. | Long space is beneficial | Long space is unfavourable |
| Confluence model | Long space is beneficial | Long space is beneficial |
| Sibling tutoring hyp. | Infinite space is a disadvantage | Unclear how tutoring quality varies with spacing |

Table 2. Summary statistics: Age intervals between siblings in two and three child families

| | Mean | Std.dev. |
|---|---|---|
| *Two child families n=35 488* | | |
| # years between 1st and 2nd | 2.914 | 1.173 |
| *Three child families n=5 840* | | |
| # years between 1st and 2nd | 2.298 | 0.864 |
| # years between 1st and 3rd | 5.016 | 1.128 |
| # years between 2nd and 3rd | 2.717 | 1.064 |

Table 3. Summary statistics: Mean test scores first born students

| | 1st born and only child | | 1st born of two children | | 1st born of three children | |
|---|---|---|---|---|---|---|
| | *Read* | *Math* | *Read* | *Math* | *Read* | *Math* |
| | 0.111 | 0.003 | | | | |
| >3 years to 2nd born | | | 0.206 | 0.170 | 0.246 | 0.260 |
| >4 years to 2nd born | | | 0.195 | 0.114 | 0.207 | 0.204 |
| >5 years to 2nd born | | | 0.161 | 0.080 | 0.265 | -0.401 |
| n | 24 076 | | 14 077 | | 519 | |
| | | | 4 004 | | 95 | |
| | | | 1 118 | | 7 | |

Table 4. Dependent variable: # years between the 1st and 2nd born in a family. Two and three child families.

| | Two child families | Three child families |
|---|---|---|
| Male | -0.002 | 0.029 |
| | (0.012) | (0.022) |
| Intact family | 0.247** | 0.116** |
| | (0.016) | (0.037) |
| Father's age | -0.007** | -0.017** |
| | (0.002) | (0.003) |
| Mother's age | -0.009** | -0.017** |
| | (0.002) | (0.004) |
| Father's educational attainment | -0.011* | 0.001 |
| | (0.005) | (0.008) |
| Mother's educational attainment | -0.029** | 0.033** |
| | (0.005) | (0.008) |
| Father's work income | -0.000 | -0.000 |
| | (0.000) | (0.000) |
| Mother's work income | 0.001** | 0.001 |
| | (0.000) | (0.001) |
| 1st generation immigrant | 0.190** | -0.378** |
| | (0.065) | (0.104) |
| 2nd generation immigrant | 0.051 | -0.071 |
| | (0.038) | (0.065) |
| # families | 35 488 | 5 840 |
| $R^2$ | 0.0113 | 0.0232 |

*Note.* Time dummies are included. Standard errors in parentheses.

**: p<0.01, *: p<0.05, +: p<0.10.

Table 5. Regression: Dependent variable: Test performance. Two child families.

| | 1st born child | | 2nd born child | |
|---|---|---|---|---|
| | *Read* | *Math* | *Read* | *Math* |
| # years between 1 and 2 | -0.014** | -0.030** | 0.006 | -0.026** |
| | (0.003) | (0.003) | (0.004) | (0.004) |
| $R^2$ | 0.1506 | 0.1369 | 0.1128 | 0.1074 |
| # student test observations | 57 317 | 57 317 | 51 424 | 51 424 |

*Note.* Controls for student and family characteristics, and time dummies are included. Standard errors in parentheses. **: p<0.01, *: p<0.05, +: p<0.10.

Table 6. Regression: Dependent variable: Test performance. Two child families.

| | 1st born child | | 2nd born child | |
|---|---|---|---|---|
| | *Read* | *Math* | *Read* | *Math* |
| # years between 1 and 2 | | | | |
| 2 | -0.003 | 0.004 | 0.098** | 0.081** |
| | (0.015) | (0.015) | (0.015) | (0.016) |
| 3 | -0.031* | -0.038* | 0.101** | 0.052** |
| | (0.015) | (0.015) | (0.016) | (0.016) |
| 4 | -0.053** | -0.068** | 0.072** | -0.006 |
| | (0.016) | (0.016) | (0.018) | (0.018) |
| 5 | -0.030 | -0.103** | 0.102** | -0.026 |
| | (0.021) | (0.022) | (0.024) | (0.024) |
| 6 | -0.018 | -0.096** | 0.082* | -0.103** |
| | (0.032) | (0.033) | (0.033) | (0.034) |
| 7 | -0.082 | -0.172** | -0.056 | -0.164** |
| | (0.082) | (0.061) | (0.061) | (0.062) |
| $R^2$ | 0.1507 | 0.1370 | 0.1137 | 0.1085 |
| # student test observations | 57 317 | 57 317 | 51 424 | 51 424 |

*Note.* Controls for student and family characteristics, and time dummies are included. Standard errors in parentheses. **: p<0.01, *: p<0.05, +: p<0.10.

Table 7. Regression: Dependent variable: Test performance. Three child families.

| | 1st born child | | 2nd born child | | 3rd born child | |
|---|---|---|---|---|---|---|
| | *Read* | *Math* | *Read* | *Math* | *Read* | *Math* |
| # years between 1 and 2 | -0.048** | -0.050** | -0.001 | -0.033** | | |
| | (0.013) | (0.014) | (0.011) | (0.008) | | |
| # years between 1 and 3 | 0.011 | 0.010 | | | -0.021 | -0.036* |
| | (0.011) | (0.011) | | | (0.014) | (0.015) |
| # years between 2 and 3 | | | -0.009 | -0.007 | 0.058** | 0.055** |
| | | | (0.008) | (0.008) | (0.015) | (0.015) |
| $R^2$ | 0.1842 | 0.1667 | 0.1570 | 0.1469 | 0.1182 | 0.1135 |
| # student test observations | 7 726 | 7 726 | 11 614 | 11 614 | 6 410 | 6 410 |

*Note.* Controls for student and family characteristics, and time dummies are included. Standard errors in parentheses. **: p<0.01, *: p<0.05, +: p<0.10.

Table 8. Regression: Dependent variable: Test performance. Three child families.

| | 1st born child | | 2nd born child | | 3rd born child | |
|---|---|---|---|---|---|---|
| | *Read* | *Math* | *Read* | *Math* | *Read* | *Math* |
| # years between 1 and 2 | | | | | | |
| 2 | -0.048+ | -0.020 | 0.068** | 0.037 | | |
| | (0.028) | (0.029) | (0.025) | (0.026) | | |
| 3 | -0.097** | -0.088* | 0.045 | -0.027 | | |
| | (0.033) | (0.035) | (0.028) | (0.028) | | |
| 4 | -0.153** | -0.146** | 0.028 | -0.068 | | |
| | (0.050) | (0.053) | (0.043) | (0.044) | | |
| 5 | -0.212* | -0.152 | -0.043 | -0.152 | | |
| | (0.096) | (0.100) | (0.097) | (0.098) | | |
| 6 | 0.007 | -0.496 | -0.076* | -0.720 | | |
| | (0.318) | (0.333) | (0.330) | (0.335) | | |
| # years between 1 and 3 | | | | | | |
| 3 | 0.163 | 0.223+ | | | 0.053 | 0.018 |
| | (0.118) | (0.124) | | | (0.135) | (0.137) |
| 4 | 0.223+ | 0.173 | | | 0.065 | 0.026 |
| | (0.117) | (0.123) | | | (0.136) | (0.138) |
| 5 | 0.205+ | 0.217+ | | | 0.034 | -0.036 |
| | (0.118) | (0.124) | | | (0.138) | (0.139) |
| 6 | 0.210+ | 0.210+ | | | -0.007 | -0.051 |
| | (0.120) | (0.125) | | | (0.140) | (0.141) |
| 7 | 0.229+ | 0.218+ | | | -0.012 | -0.125 |
| | (0.124) | (0.130) | | | (0.146) | (0.147) |
| # years between 2 and 3 | | | | | | |
| 2 | | | -0.048 | -0.084** | 0.083* | 0.100* |
| | | | (0.032) | (0.032) | (0.041) | (0.041) |
| 3 | | | -0.019 | -0.057+ | 0.156** | 0.166** |
| | | | (0.032) | (0.032) | (0.046) | (0.047) |
| 4 | | | -0.093** | -0.076* | 0.194** | 0.183** |
| | | | (0.034) | (0.035) | (0.055) | (0.055) |
| 5 | | | 0.032 | -0.056 | 0.232** | 0.229** |
| | | | (0.049) | (0.050) | (0.075) | (0.076) |
| 6 | | | -0.277+ | -0.244 | 0.203 | 0.303+ |
| | | | (0.161) | (0.163) | (0.175) | (0.176) |
| $R^2$ | 0.1848 | 0.1675 | 0.1594 | 0.1484 | 0.1187 | 0.1144 |
| # student test observations | 7 726 | 7 726 | 11 614 | 11 614 | 6 410 | 6 410 |

*Note.* Controls for student and family characteristics, and time dummies are included. Standard errors in parentheses. **: p<0.01, *: p<0.05, +: p<0.10.

Table 9. Regression: Dependent variable: Test performance. Two child families. Mother's education at college, university or PhD level.

| | 1st born child | | 2nd born child | |
|---|---|---|---|---|
| | *Read* | *Math* | *Read* | *Math* |
| # years between 1 and 2 | | | | |
| 2 | 0.053* | 0.054* | 0.103** | 0.083** |
| | (0.021) | (0.022) | (0.023) | (0.023) |
| 3 | 0.029 | 0.019 | 0.096** | 0.043+ |
| | (0.021) | (0.022) | (0.023) | (0.023) |
| 4 | 0.034 | 0.000 | 0.075** | -0.026 |
| | (0.023) | (0.024) | (0.026) | (0.027) |
| 5 | 0.050 | -0.045 | 0.076* | -0.051 |
| | (0.031) | (0.032) | (0.036) | (0.037) |
| 6 | 0.016 | -0.071 | -0.010 | -0.185** |
| | (0.050) | (0.053) | (0.053) | (0.054) |
| 7 | -0.161+ | -0.190* | -0.163+ | -0.287** |
| | (0.091) | (0.096) | (0.095) | (0.099) |
| $R^2$ | 0.0894 | 0.0836 | 0.0708 | 0.0707 |
| # student test observations | 27 093 | 27 093 | 23 671 | 23 671 |

*Note.* Controls for student and family characteristics, and time dummies are included. Standard errors in parentheses. **: p<0.01, *: p<0.05, +: p<0.10.

Table 10. Regression: Dependent variable: Test performance. Two child families. Mother's education at the high school level.

| | 1st born child | | 2nd born child | |
|---|---|---|---|---|
| | *Read* | *Math* | *Read* | *Math* |
| # years between 1 and 2 | | | | |
| 2 | -0.039+ | -0.035 | 0.088** | 0.091** |
| | (0.024) | (0.024) | (0.025) | (0.025) |
| 3 | -0.070** | -0.082** | 0.094** | 0.072** |
| | (0.023) | (0.024) | (0.025) | (0.025) |
| 4 | -0.111** | -0.114** | 0.062* | 0.034 |
| | (0.025) | (0.026) | (0.027) | (0.028) |
| 5 | -0.086** | -0.154** | 0.117** | -0.001 |
| | (0.032) | (0.033) | (0.036) | (0.037) |
| 6 | -0.032 | -0.109* | 0.116* | -0.045 |
| | (0.049) | (0.050) | (0.051) | (0.051) |
| 7 | 0.021 | -0.119 | 0.018 | -0.106 |
| | (0.090) | (0.092) | (0.094) | (0.095) |
| $R^2$ | 0.0793 | 0.0567 | 0.0562 | 0.0467 |
| # student test observations | 24 235 | 24 235 | 22 005 | 22 005 |

*Note.* Controls for student and family characteristics, and time dummies are included. Standard errors in parentheses. **: p<0.01, *: p<0.05, +: p<0.10.

Table 11. Regression: Dependent variable: Test performance. Two child families. Mother's educational attainment lower secondary school (compulsory education), or less.

| | 1st born child | | 2nd born child | |
|---|---|---|---|---|
| | *Read* | *Math* | *Read* | *Math* |
| # years between 1 and 2 | | | | |
| 2 | -0.063 | -0.033 | 0.105* | 0.037 |
| | (0.044) | (0.043) | (0.043) | (0.042) |
| 3 | -0.121** | -0.097* | 0.148** | 0.013 |
| | (0.045) | (0.044) | (0.044) | (0.043) |
| 4 | -0.167** | -0.163** | 0.095+ | -0.071 |
| | (0.048) | (0.047) | (0.050) | (0.049) |
| 5 | -0.116+ | -0.140* | 0.132+ | -0.023 |
| | (0.062) | (0.061) | (0.064) | (0.066) |
| 6 | -0.112 | -0.178* | 0.187* | -0.092 |
| | (0.085) | (0.083) | (0.085) | (0.083) |
| 7 | -0.219 | -0.306* | -0.023 | -0.059 |
| | (0.158) | (0.154) | (0.159) | (0.156) |
| $R^2$ | 0.0949 | 0.0803 | 0.0420 | 0.0564 |
| # student test observations | 5 989 | 5 989 | 5 748 | 5 748 |

*Note.* Controls for student and family characteristics, and time dummies are included. Standard errors in parentheses. **: p<0.01, *: p<0.05, +: p<0.10.

Table 12. Regression: Dependent variable: Test performance. Three child families. Mother's education at college, university or PhD level.

| | | 1st born child | | 2nd born child | | 3rd born child | |
|---|---|---|---|---|---|---|---|
| | | *Read* | *Math* | *Read* | *Math* | *Read* | *Math* |
| # years between 1 and 2 | | | | | | | |
| | 2 | -0.091* | -0.051 | 0.033 | 0.043 | | |
| | | (0.037) | (0.040) | (0.034) | (0.035) | | |
| | 3 | -0.137** | -0.136** | -0.001 | -0.031 | | |
| | | (0.044) | (0.047) | (0.037) | (0.038) | | |
| | 4 | -0.237** | -0.183* | 0.057 | -0.023 | | |
| | | (0.066) | (0.072) | (0.058) | (0.060) | | |
| | 5 | -0.324** | -0.314* | 0.024 | -0.073 | | |
| | | (0.124) | (0.134) | (0.130) | (0.133) | | |
| | 6 | -0.158 | -0.537 | -0.881+ | -1.340** | | |
| | | (0.453) | (0.489) | (0.486) | (0.498) | | |
| # years between 1 and 3 | | | | | | | |
| | 3 | 0.757** | 0.410* | | | 0.054 | 0.306 |
| | | (0.184) | (0.198) | | | (0.223) | (0.228) |
| | 4 | 0.799** | 0.357+ | | | 0.001 | 0.259 |
| | | (0.183) | (0.197) | | | (0.224) | (0.229) |
| | 5 | 0.823** | 0.425* | | | 0.002 | 0.183 |
| | | (0.184) | (0.198) | | | (0.225) | (0.230) |
| | 6 | 0.831** | 0.440* | | | -0.074 | 0.152 |
| | | (0.185) | (0.200) | | | (0.227) | (0.232) |
| | 7 | 0.832** | 0.462* | | | -0.102 | 0.088 |
| | | (0.190) | (0.205) | | | (0.235) | (0.240) |
| # years between 2 and 3 | | | | | | | |
| | 2 | | | -0.029 | -0.065 | 0.084 | 0.068 |
| | | | | (0.043) | (0.045) | (0.057) | (0.058) |
| | 3 | | | -0.015 | -0.048 | 0.150* | 0.141* |
| | | | | (0.044) | (0.045) | (0.064) | (0.066) |
| | 4 | | | -0.074 | -0.068 | 0.246** | 0.191* |
| | | | | (0.047) | (0.048) | (0.076) | (0.077) |
| | 5 | | | 0.054 | 0.009 | 0.237* | 0.202+ |
| | | | | (0.067) | (0.068) | (0.105) | (0.107) |
| | 6 | | | -0.402+ | -0.153 | 0.214 | 0.092 |
| | | | | (0.223) | (0.229) | (0.246) | (0.251) |
| $R^2$ | | 0.1078 | 0.0921 | 0.0898 | 0.0889 | 0.0776 | 0.0762 |
| # student test observations | | 4 214 | 4 214 | 6 381 | 6 381 | 3 456 | 3 456 |

*Note.* Controls for student and family characteristics, and time dummies are included. Standard errors in parentheses. **: p<0.01, *: p<0.05, +: p<0.10.

Table 13. Regression: Dependent variable: Test performance. Three child families. Mother's education at the high school level.

| | 1st born child | | 2nd born child | | 3rd born child | |
|---|---|---|---|---|---|---|
| | *Read* | *Math* | *Read* | *Math* | *Read* | *Math* |
| # years between 1 and 2 | | | | | | |
| 2 | 0.010 | -0.007 | 0.081+ | 0.037 | | |
| | (0.048) | (0.049) | (0.043) | (0.043) | | |
| 3 | -0.055 | -0.055 | 0.078+ | 0.001 | | |
| | (0.058) | (0.058) | (0.047) | (0.048) | | |
| 4 | -0.069 | -0.193* | -0.124+ | -0.173* | | |
| | (0.085) | (0.086) | (0.072) | (0.073) | | |
| 5 | -0.156 | -0.011 | -0.119 | -0.165 | | |
| | (0.168) | (0.171) | (0.165) | (0.168) | | |
| 6 | 0.276 | -0.407 | -0.896+ | -0.040 | | |
| | (0.518) | (0.526) | (0.519) | (0.528) | | |
| # years between 1 and 3 | | | | | | |
| 3 | 0.026 | 0.230 | | | -0.052 | 0.009 |
| | (0.198) | (0.201) | | | (0.220) | (0.221) |
| 4 | 0.103 | 0.176 | | | 0.052 | 0.063 |
| | (0.196) | (0.199) | | | (0.221) | (0.223) |
| 5 | 0.039 | 0.170 | | | -0.046 | -0.041 |
| | (0.198) | (0.200) | | | (0.222) | (0.224) |
| 6 | 0.068 | 0.151 | | | -0.033 | -0.023 |
| | (0.200) | (0.203) | | | (0.228) | (0.229) |
| 7 | 0.061 | 0.107 | | | -0.053 | -0.118 |
| | (0.207) | (0.210) | | | (0.237) | (0.239) |
| # years between 2 and 3 | | | | | | |
| 2 | | | -0.091+ | -0.170** | 0.080 | 0.153* |
| | | | (0.052) | (0.053) | (0.067) | (0.067) |
| 3 | | | -0.046 | -0.115* | 0.180* | 0.244** |
| | | | (0.053) | (0.054) | (0.076) | (0.076) |
| 4 | | | -0.162** | -0.148* | 0.135 | 0.205* |
| | | | (0.057) | (0.058) | (0.090) | (0.091) |
| 5 | | | 0.008 | -0.139+ | 0.224+ | 0.372** |
| | | | (0.080) | (0.081) | (0.123) | (0.124) |
| 6 | | | -0.101 | -0.310 | 0.114 | 0.499+ |
| | | | (0.257) | (0.261) | (0.278) | (0.280) |
| $R^2$ | 0.0986 | 0.1116 | 0.0718 | 0.0634 | 0.0491 | 0.0641 |
| # student test observations | 2 790 | 2 790 | 4 154 | 4 154 | 2 321 | 2 321 |

*Note.* Controls for student and family characteristics, and time dummies are included. Standard errors in parentheses. **: p<0.01, *: p<0.05, +: p<0.10.

Table 14. Regression: Dependent variable: Test performance. Three child families. Mother's educational attainment lower secondary school (compulsory education), or less.

| | 1st born child | | 2nd born child | | 3rd born child | |
|---|---|---|---|---|---|---|
| | *Read* | *Math* | *Read* | *Math* | *Read* | *Math* |
| # years between 1 and 2 | | | | | | |
| 2 | -0.101 | 0.037 | 0.114 | -0.041 | | |
| | (0.100) | (0.098) | (0.082) | (0.078) | | |
| 3 | -0.105 | -0.019 | 0.110 | -0.112 | | |
| | (0.113) | (0.116) | (0.089) | (0.083) | | |
| 4 | -0.157 | 0.103 | 0.379* | 0.031 | | |
| | (0.178) | (0.182) | (0.153) | (0.145) | | |
| 5 | -0.012 | 0.027 | -0.172 | -0.427 | | |
| | (0.317) | (0.325) | (0.312) | (0.296) | | |
| 6 | -0.481 | -0.700 | -0.091 | -0.869 | | |
| | (0.936) | (0.960) | (0.948) | (0.897) | | |
| # years between 1 and 3 | | | | | | |
| 3 | -0.560* | 0.084 | | | 0.314 | -0.108 |
| | (0.283) | (0.290) | | | (0.301) | (0.280) |
| 4 | -0.412 | 0.083 | | | 0.316 | -0.071 |
| | (0.281) | (0.288) | | | (0.310) | (0.288) |
| 5 | -0.542 | 0.110 | | | 0.316 | -0.014 |
| | (0.281) | (0.294) | | | (0.317) | (0.295) |
| 6 | -0.635 | 0.090 | | | 0.237 | 0.012 |
| | (0.296) | (0.303) | | | (0.330) | (0.307) |
| 7 | -0.438 | 0.160 | | | 0.386 | -0.110 |
| | (0.315) | (0.323) | | | (0.349) | (0.324) |
| # years between 2 and 3 | | | | | | |
| 2 | | | -0.044 | 0.108 | 0.066 | 0.067 |
| | | | (0.101) | (0.096) | (0.127) | (0.118) |
| 3 | | | 0.030 | 0.092 | 0.085 | 0.070 |
| | | | (0.103) | (0.098) | (0.145) | (0.135) |
| 4 | | | -0.025 | 0.094 | 0.139 | 0.080 |
| | | | (0.108) | (0.103) | (0.175) | (0.163) |
| 5 | | | 0.038 | -0.124 | 0.308 | -0.073 |
| | | | (0.171) | (0.162) | (0.241) | (0.224) |
| 6 | | | -0.586 | -0.565 | 0.664 | 0.842 |
| | | | (0.560) | (0.530) | (0.590) | (0.163) |
| $R^2$ | 0.1542 | 0.0898 | 0.1030 | 0.1389 | 0.0964 | 0.0884 |
| # student test observations | 722 | 722 | 1 079 | 1 079 | 633 | 633 |

*Note.* Controls for student and family characteristics, and time dummies are included. Standard errors in parentheses. **: p<0.01, *: p<0.05, +: p<0.10.

Table 15. Regression: Dependent variable: Test performance.
Same-sex sibships. Two child families

| All girls | 1st born child | | 2nd born child | |
|---|---|---|---|---|
| | *Read* | *Math* | *Read* | *Math* |
| # years between 1 and 2 | -0.012+ | -0.026** | 0.000 | -0.027** |
| | (0.007) | (0.007) | (0.007) | (0.008) |
| $R^2$ | 0.1316 | 0.1363 | 0.1068 | 0.1029 |
| # student test observations | 13 648 | 13 648 | 12 220 | 12 220 |

| All boys | 1st born child | | 2nd born child | |
|---|---|---|---|---|
| | *Read* | *Math* | *Read* | *Math* |
| # years between 1 and 2 | 0.000 | -0.019** | 0.026** | -0.017* |
| | (0.007) | (0.007) | (0.007) | (0.008) |
| $R^2$ | 0.1399 | 0.1398 | 0.1045 | 0.1022 |
| # student test observations | 13 716 | 13 716 | 12 357 | 12 357 |

*Note.* Controls for student and family characteristics, and time dummies are included. Standard errors in parentheses. **: p<0.01, *: p<0.05, +: p<0.10.

Table 16. Regression: Dependent variable: Test performance.
Same-sex sibships. Three child families.

| All girls | 1st born child | | 2nd born child | | 3rd born child | |
|---|---|---|---|---|---|---|
| | *Read* | *Math* | *Read* | *Math* | *Read* | *Math* |
| # years between 1 and 2 | -0.069+ | -0.054 | 0.061+ | 0.035 | | |
| | (0.037) | (0.038) | (0.031) | (0.033) | | |
| # years between 1 and 3 | 0.007 | 0.001 | | | 0.014 | 0.019 |
| | (0.030) | (0.032) | | | (0.041) | (0.043) |
| # years between 2 and 3 | | | 0.047* | 0.039 | 0.025 | 0.034 |
| | | | (0.024) | (0.025) | (0.041) | (0.043) |
| $R^2$ | 0.1930 | 0.1947 | 0.1639 | 0.1570 | 0.1178 | 0.1288 |
| # student test obs. | 881 | 881 | 1 315 | 1 315 | 735 | 735 |

| All boys | 1st born child | | 2nd born child | | 3rd born child | |
|---|---|---|---|---|---|---|
| | *Read* | *Math* | *Read* | *Math* | *Read* | *Math* |
| # years between 1 and 2 | -0.114** | -0.107** | 0.004 | -0.060* | | |
| | (0.036) | (0.037) | (0.030) | (0.030) | | |
| # years between 1 and 3 | 0.043 | 0.071* | | | 0.011 | 0.014 |
| | (0.030) | (0.031) | | | (0.040) | (0.039) |
| # years between 2 and 3 | | | -0.011 | -0.002 | 0.021 | 0.014 |
| | | | (0.024) | (0.024) | (0.043) | (0.042) |
| $R^2$ | 0.1842 | 0.1667 | 0.1570 | 0.1469 | 0.1182 | 0.1135 |
| # student test obs. | 7 726 | 7 726 | 11 614 | 11 614 | 6 410 | 6 410 |

*Note.* Controls for student and family characteristics, and time dummies are included. Standard errors in parentheses. **: p<0.01, *: p<0.05, +: p<0.10.