The effect of birth order and family size on educational outcomes in Germany:

An empirical assessment of the quantity-quality trade-off of children

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Academic year 2020/2021

In order to obtain the Double Degree
Master 120 en Sciences économiques, Orientation générale, Finalité spécialisée
(UCL/UNamur)
and
Master of Science in Economic Studies
(Maastricht University)

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Acknowledgements

I would like to thank Prof. Dr. Steffen Künn from Maastricht University and Prof. Dr. Catherine Guirkinger from Université de Namur for their continuous support and insightful comments throughout the process of writing this thesis. Your insightful feedback kept me in the right direction to successfully complete this work.

Abstract

By employing German longitudinal data from 2006 to 2017, this paper studies the causal effect of family size and birth order on educational outcomes in terms of school levels and test scores. The quantity-quality trade-off model of children envisages a negative trade-off between child quantity and -quality; children from larger families are to experience lower child quality due to fixed budget constraints. In addition, a higher birth order is expected to influence child quality negatively due to the possibility of additional time constraints and depletion of resources. To ensure the exogeneity of family size, an instrumental variable approach based on multiple births and the gender composition of the first two children is applied. Furthermore, a variable for relative birth order is generated to guarantee the full reduction of correlation between birth order and family size. The causal results suggest that with inclusion of said instrumental variables, the child quantity-quality model is overall, no longer supported. Nevertheless, birth order seems to relate negatively to the chances of a last-born in attending higher secondary education compared to the first-born within the same household. Studying the effect of family size and birth order to children's outcomes has the potential to contribute to the understanding of the determinants of child welfare and economics of fertility, and eventually provide policy implications to promote economic development in both developed- and developing countries.

Keywords: quantity-quality trade-off, position in birth order, intra-household resource allocation, economics of fertility, education

Table of contents

1. Introduction

Existing literature often focusses on investigating the drivers of poverty and inequality from a macroeconomics perspective. Yet, knowledge about exact dynamics from a microeconomics standpoint, in example between and within households itself, is scarcer. Empirically, examining these dynamics proves challenging. The occurrence of public goods and collection of data at a household level both partly hinder the intrahousehold resource allocation analysis. Nevertheless, a long tradition of economists being interested in studying the factors that promote individual child welfare persists. Two of the most prominent factors are family size and birth order. A well-established theoretical model which aims to understand the relation between child outcomes and family size is the quantity-quality model presented by Becker (1960). Becker (1960) initially introduced this model because of an observed negative correlation between household income and family size. Given the assumption of a fixed household budget constraint, to increase child quality (resources spent on the child) child quantity (family size) must decrease, thus resulting in a negative relation between quantity and quality. Next to family size, birth order causes an additional trade-off now concentrated on children from the same households: Additional time constraints and depletion of resources predict that children with a relatively larger birth order receive, on average, fewer resources. Empirically investigating the exact relation between family size and birth order to child welfare is of great importance since it has the potential to increase our understanding about topics such as intrahousehold resource allocation, the demographic transition, increased demand for human capital, and economic development in both developed- and developing countries (Fernihough, 2017; Galor and Weil, 2000; Galor and Moav, 2002). Moreover, the child quantity-quality trade-off model can provide important policy implications about fertility levels and quality of schools, particularly in developing countries where high fertility rates and poverty simultaneously persist (Moav, 2005).

Nevertheless, the main question that remains to be asked is whether this trade-off is real? Does coming from a larger family or having a larger birth order cause a negative effect on "child quality"? Or are families who choose to have more children inherently different than smaller sized families, and thus, would children with more siblings perform worse in schools irrespective of their initial family size? While the quality-quantity trade-off model theoretically is well established, the empirical literature often lacks a consensus about the relationship between family size, birth order, and child quality. Establishing a true causal relation between the said variables is challenging due to the endogeneity of family size and the confounding strong positive correlation between family size and birth order. Whereas OLS results mainly provide evidence for the existence of the child quantity-quality trade-off, the use of instrumental variables to account for endogeneity problems often provides no such support.

This paper aims to examine the causal effect of family size and birth order on educational outcomes in terms of school levels and test scores in Germany. In this way, the said educational outcomes act as a proxy for "child quality". Hence, this paper attempts to empirically verify whether the child quantity-quality trade-off model exists while taking into account the possible confounding effect of birth order. Following the theoretical model, hypotheses are that both family size and the position in birth order negatively relate to educational outcomes. By using German survey data from 2006 to 2017 provided by the SOEP-Core, this paper is able to use an exogenous source of variation of family size based on the use of two well-known instrumental variables: (1) *the occurrence of twin birth* following Rosenzweig and Wolpin (1980) and (2) *the sex-mix of the first two children* introduced by Angrist and Evans (1998). Moreover, a variable for the relative birth order is generated which indirectly considers family size and hence, eliminates the existing positive initial correlation between family size and birth order.

Results suggests that while simple OLS estimates confirm the expected negative relation between family size and birth order to the chances of attending certain school levels, with inclusion of said instrumental variables, the child quantity-quality model is no longer supported. Nevertheless, simultaneously, some significant yet small birth order effects seem to exist. Results imply that the last-born child's chances of attending higher secondary education fall by 2.5 percentage points compared to being the first-born within the same household. In contrast to using school levels as dependent variables, the results corresponding to test scores are less clear. No real negative relation between family size and birth order to test scores is found. With using mathematics test scores as a response variable, results even suggest that an increase in family size seems to improve the said test scores by 0.32 standard deviations.

This paper adds to the existing literature by providing causal evidence for the quantity-quality trade-off of children and the influence of position in birth order to educational outcomes by exploiting more recent data from Germany. Compared to previous literature which mainly employed relative older German data from the 1980s and solely used fixed effects models, this paper is the first to use more recent German data while simultaneously exploiting exogenous variation. Due to the use of instrumental variables, this paper is able to isolate the causal effect of family size and birth order to educational outcomes in Germany, while, at the same time, reducing the plausible correlation between family size and birth order. Hence, this paper is able to contribute to the creation of external validity around the quantity-quality trade-off model of children with the implementation of more recent data.

The remainder of this paper is structured as follows. Section 2 reviews relevant literature about the relation between family size, birth order and education, thereby, introducing the quantity-quality trade-off model in more detail, highlighting the possible effects of birth order to child quality, and discussing the challenges of this empirical analysis. Section 3 presents the data and provides some institutional details about German schools and its grading system. Section 4 explains the methodology used in this paper, the two different dependent variables employed, and the overall hypotheses. Section 5 discusses the main results and presents some limitations of this empirical analysis. Section 6 concludes this paper and provides both some suggestions for policy implications and future research.

2. Existing literature on the effects of family size and birth order on education

This literature review will first introduce the quantity-quality trade-off by Becker (1960) by theoretically analysing the effect of family size and birth order to child quality in the form of education. Subsequently, main results from existing literature will be discussed with methodological considerations to reduce exogeneity problems and to eliminate the existing correlation between family size and birth order.

2.1. Family size and education: The theory of the quantity-quality trade-off

By examining to which extent family size and birth order influence educational outcomes in Germany, this paper will add to the existing literature on the quantity-quality trade-off of children firstly described by Becker (1960). Becker (1960) was the first to include family size decisions and human behaviour in an economic framework. Before Becker’s empirical work, fertility choices were only considered to be part of sociology and demography and hence, disregarded from any economic analyses. With his contribution, Becker (1960) introduced a quantity-quality trade-off model to explain the observable negative relationship between fertility and family income. According to Becker (1960), children can be perceived as consumer durables, just as cars or houses. When couples decide on their desired fertility levels, a quantity-quality trade-off for children arises. In his model, quantity is defined as the number of children, while quality is measured as the resources spent on each child (Becker and Lewis, 1973; Becker and Tomes, 1976). Both the quality and quantity of a child gives parents utility. Furthermore, these preferences are assumed to be given, which allows to base the choice of fertility solely to income and relative price effects.

Although child-quantity and -quality might give parents separate utilities, according to Becker and Lewis (1973), quality and quantity are still interlinked through the households' fixed budget constraint. Under this assumption a trade-off arises; if the amount of resources spent on children increases (child quality), maintaining child quantity becomes more costly since there is only a fixed amount of budget available. Consequently, to increase child quality, child quantity must decrease. Likewise, when parents have more children (child quantity), the amount of resources spent per child will become more costly, and therefore, investments per child will have to be reduced. Hence, child quantity and -quality are negatively related under the assumption of a fixed family income.

2.2. Birth order and education: Why a child's position in his/her sibship might matter

Besides family size, the existing literature has established that birth order also influences child quality (Zajonc, 1976; Behrman, 1997; De Haan, 2005). Zajonc (1976) argues that a negative correlation between a child's intellect and its birth order exists. According to Zajonc (1976), the intellect of children depends on the intellectual environment in which they grow up. This intellectual environment is defined as the average of the intellectual level of all the family members. In this case, the first-born holds an advantage over the later born children, since with each additional child, the average of the intellectual environment decreases. In addition to children's direct environment, time and budget constraints are also expected to influence the role of birth order to child quality. Behrman (1997) argues that, assuming that parents have a fixed time endowment, the first-born will receive a greater share of time spent with the parents than is possible for any subsequent children. Given that more time spent with the parents raises child quality, first-born children have a clear advantage. Besides time constraints, budget constraints also play a role; parents are not always fully forward looking, or they simply cannot estimate the amount of resources needed to be invested in their children. In this case, later born children might be left with relatively fewer resources since their siblings already depleted most of them (De Haan, 2005).

2.3.Family size, birth order and education in the empirical literature: Main results

The quantity-quality trade-off model has frequently been empirically estimated within the field of economics (Rosenzweig and Wolpin, 1980; Blake, 1981; Behrman and Taubman, 1986; Angrist and Evans, 1998; Hanushek, 1992; De Haan, 2005; Angrist, Lavy, and Schlosser, 2005; Black, Devereux, and Salvanes, 2005; and Eschelbach, 2013; Härkönen, 2014; Mogstad and Wiswall, 2016). In most empirical studies, the investments per child are measured through the effect on educational outcomes in for example children's schooling attainment, thereby taking educational attainment as an indicator of child quality. Theoretically, for a given level of parental income, a larger family size decreases the amount of resources per capita available for educational investments, which in turn, should result in lower educational attainment and/or reduced test grades. Moreover, due to time and budget constraints, birth order is also expected to be negatively correlated to educational outcomes. Even though the empirical results around birth order are more varied, Blake (1981) and Hanushek (1992) both discover a negative relationship between family size and education. Blake (1981) establishes a negative relationship between family size and educational attainment when employing survey data from the United States. However, for the effect of birth order, no systematic difference in educational attainment is found between first- and later born children. Hanushek (1992) investigates the relation between family size and test scores from the Iowa Reading Comprehension and Vocabulary tests. He finds support for the quantity-quality trade-off of children in real life by the confirmed significant negative relation between family size and test scores. However, regarding birth order, Hanushek (1992) does not find any significant results either. His results even suggest that in larger families, being a last-born holds an advantage over being the first-born in the family since the last-born does not have to compete for time of his or her parents with younger siblings. In contrast to Hanushek (1992), Behrman and Taubman (1986) do find a negative relationship between birth order and educational outcomes. They investigate the effect of birth order to schooling and earnings from US young adults. Their paper suggests that, even after controlling for family size, first-born children have an advantage in terms of schooling but not for earnings than later born children. However, they use a relatively small representative data set of about 1000 individuals, which casts doubt over the external validity of their research.

Both Härkönen (2014) and Eschelbach (2013) estimated the relationship between birth order and family size to educational attainment in Germany before using a fixed effects model. Eschelbach (2013) finds a significant positive impact of being a first-born on the probability of completing secondary education. In addition, she establishes that birth order effects are predominant in smaller families. Härkönen (2014) finds similar results as Eschelbach (2013); he suggests that birth order has a strong negative impact on educational attainment in West-Germany. Nonetheless, both papers use relative old data from 1946 to 1999 and hence, by using data from 2006-2017, this paper hopes to draw more relevant conclusions about the differences between siblings within- and between families in Germany.

2.4. Family size, birth order and education in the empirical literature: Methodological considerations

Even though, Blake (1981), Hanushek (1992), Behrman and Taubman (1986), Härkönen (2014) and Eschelbach (2013) results partly confirm the expected direction, empirically studying the relation between family size, birth order, and educational outcomes entails two main concerns. The first issue is the persistent positive correlation between family size and birth order. A first-born child has a larger probability of being a member of a smaller family than a child with a relatively larger birth order. Thus, without explicitly controlling for birth order in the empirical model, the effect of family size to educational outcomes is likely to pick up the potential birth order effect and hence, will lead to biased results. The second main problem is the endogeneity of the variable family size. The number of children a couple decides to have is likely to be endogenous to educational outcomes, meaning that family size might depend on other unobservable parental characteristics that determine a child's educational outcome. Hence, without ensuring the exogeneity of family size, results cannot be interpreted causally.

Not all research has successfully addressed the aforementioned problems, mainly due to scarcity of birth order data and the lack of relevant exogenous proxies for family size. For instance, even though, both Blake (1981) and Hanushek (1992) establish a negative relationship between family size and educational outcomes, the endogeneity problem of family size has not been dealt with, and therefore, the found results can merely be interpreted as correlation. Furthermore, although Behrman and Taubman (1986) do control for family size, this does not reduce the existing correlation between family size and birth order. Moreover, while both Härkönen (2014) and Eschelbach (2013) use a fixed effects model to control for any unobservable characteristics, they are still not fully able to control for the endogeneity problem of family size.

A popular method to correct for the endogeneity problem of family size is to employ an instrumental variables (IV) approach. Rosenzweig and Wolpin (1980) attempt to use twin-births as an exogenous source of variation for family size while using household data from India. Using twin-births is accepted as a valid IV due to both its relevance and exogeneity. It is relevant since the occurrence of a twin or multiple birth increases the family size directly. Furthermore, the birth of a twin will vary the actual family size from the desired one, this therefore, leads to exogeneity and enables to investigate the causal effects of family size to child outcomes. Rosenzweig and Wolpin (1980) do find results in the expected direction; increases in family size tend to decrease child quality. However, in their paper, they do not include controls for birth order, therefore, possibly confounding its effects with family size. Instead of using multiple births as an IV, Angrist and Evans (1998) use the sex composition of the first two children to exploit exogenous variation in family size since the occurrence of twins is relatively scarce. Assuming that parents prefer a mixed sibling-sex composition, having two boys or two girls would increase the probability of parents wanting one more child. Since gender is exogenously determined, the sex-mix of the first two children would provide a valid instrument. Even though, Angrist and Evans (1998) in their paper did not directly investigate the quantity-quality trade-off of children, their instrumental variable approach was later used by Angrist, Levy, Schlosser (2005), Black, Devereux, and Salvanes (2005), and De Haan (2005).

More recent papers have managed to both employ an IV approach while simultaneously separate the effect between birth order and family size, using data from different countries. By including dummy variables for the absolute birth order or using a relative birth rank following Ejrnaes and Portner (2004), the existing correlation between family size and birth order can be removed. Dummy variables for each birth rank are included, besides the variable family size, to distinguish its effect to child quality. In contrast, a relative birth rank is a generated variable which ensures that the initial correlation between family size and the absolute birth order fully disappears and takes indirectly the size of the family into account. Hence, allowing to distinguish between second-born children from larger- and smaller families.

Black et al. (2005) uses multiple births as an instrumental variable for family size and birth order dummies to investigate the possible causal relation of sibship size and birth order to educational attainment using a rich data set from Norway. Initially, when using an ordinary least squares (OLS) regression, Black et al. (2005) do find the suspected negative relation. However, after implementing the multiple births instrument, adding dummies for birth order, and adding many control variables such as parents' education, no significant relationship between family size and children's educational attainment is found. On the contrary, birth order is found to be significant and negatively related to educational attainment; a higher birth order results in a negative effect on children's education. In addition to educational outcomes, Black et al. (2005) also study the effect of birth order and sibship size to earnings, employment, and the age of childbearing. Results find a negative relationship between birth order and the said dependent variables, showing that there is a need for research to also focus on intra-household differences.

Mogstad and Wiswall (2016) adopt Black et al. (2005) empirical strategy and use the same data set from Norway. However, in their research, Mogstad and Wiswall (2016) allow for the possibility of a non-linear relationship between family size and educational outcomes, which did result in finding a substantial negative family size effect to educational attainment. Besides the Norwegian data, De Haan (2005) uses both Dutch as well as American data to adopt a similar approach as Black et al. (2005), while also including both the twins and sex-composition of the first two children as possible IV strategies. De Haan (2005) investigates to which extent the number of children does affect educational attainment of the oldest child. Results initially suggest a negative relation persists. However, after the inclusion of the different IV's, the coefficients become insignificant suggesting that other unobserved variables might explain the initially established negative relation. Angrist, Lavy, and Schlosser (2005) study the effect of family size and birth order to educational attainment, fertility, and earnings by using Israeli Census data. In addition, they include ethnic differences to show the gender preferences in some families. After the implementation of the IV strategy based on twin births and the sex-mix of the first two children, their results do not find any proof of the child quantity-quality trade-off. Table A.1. in the Appendix provides a brief summary of all the studies discussed in this section.

While the said results might be due to specificities in the data, data from other countries must be analysed as well to contribute to the creation of external validity. That is why this paper contributes to the existing literature by being the first to analyse the causal effect of birth order and family size to education outcomes in Germany by exploiting more recent data and employing the two well-established instrumental variables approaches; (1) *multiple-births* following Rosenzweig and Wolpin (1980) and (2) *the sex-mix of the first two children* described by Angrist and Evans (1998). Thus, this paper attempts to eliminate the possibility that the number of children a couple decides to have is endogenous to educational outcomes and therefore, this paper aims to interpret results causally. Furthermore, in addition to Black et al. (2005), this paper employs the use of a relative birth rank instead of dummy variables to fully decrease the correlation between family size and birth order (Ejrnaes and Portner, 2004). Hence, the separate effect of family size and birth order to educational outcomes can be estimated.

3. Data collection and the German schooling system

This section discusses how the German data used in this paper is collected, provides some more specific institutional details about the German schooling system, and explains the functioning of the German grading scale. In addition, general descriptive statistics are depicted to illustrate how family size and birth order relate to educational outcomes in terms of school levels and test scores.

3.1. The SOEP-Core

To estimate the relation between family size, birth order, and educational outcomes in Germany, longitudinal data is collected from the Socio-Economic Panel (SOEP-Core) study (SOEP, n.d.). The SOEP-Core is a representative household study, where every year, the same households and each individual member are surveyed about various topics such as health, employment, education, families and social networks, and values and personality (Goebel, Grabka, Liebig, Kroh, Richter, Schröder, and Schupp, 2019). Specifically, for the purpose of this paper, data from 2006 to 2017 of the SOEP-Core 16-17-year-olds youth questionnaire is extracted. Within this specific survey, each year, different 16-17-year olds, whose households participate in the SOEP, are surveyed and information can be retrieved about their school level, educational performance, relationship to their parents, living situation, and future educational-and occupational plans. Furthermore, additional data from the individual-, household-, and generated biographical information of the years 2006 to 2017 is collected to retrieve supplementary information about the 16-17-year olds' number of brothers and sisters, family size, birth order, federal state, household income, parents' education level, gender, and date of birth. Hence, the SOEP-Core provides an extremely rich dataset that allows to perform the empirical analysis about the quantity-quality trade-off of having children and role of birth order this paper attempts to answer.

Table 1 presents summary statistics for the sample used in this paper. The sample is restricted to those 16-17-year olds who at the time of questionnaire attended school. In total, there are 4858 16-17-year olds, coming from various households distributed across Germany. The variable *"Family Size"* refers to the number of siblings documented in the SOEP. Hence, the measure for family size is a completed family size measure indicating the number of children of a household known by the SOEP. On average, German families seem to have three children. In addition, the variable for *"Position in birth order"* indicates the absolute level of birth order compared to the siblings documented by the SOEP. Most pupils are born second within their family. Since usually all family members are precisely documented by the SOEP, it is not expected that this should cause any bias in case some siblings are not documented.

Table 1. Summary statistics

	N	Mean	Std. Dev.	min	max
Family Size	4858	2.78	1.313	1	12
Grade German	4180	2.876	.844	1	6
Grade Foreign Language	4133	2.917	.938	1	6
Grade Mathematics	4182	2.975	1.06	1	6
Household Net Income	4924	3363.926	2066.147	100	45000
Position in birth order	4858	1.719	.931	1	10
Satisfaction With Overall School Grades	5064	6.601	1.984	0	10
Sex	4467	1.503	.5	1	2
Survey Year	5202	2012.337	3.299	2006	2017
Year of Birth	5186	1995.327	3.299	1989	2000

More specifically, Table 2 depicts the relation between birth order and family size of the German households included in this sample. As illustrated, families with more than seven children are quite rare: only 72 pupils (1.48%) are born into a family with more than seven children. Hence, the actual occurrence of a large position in birth order is therefore, also relatively scarce. Only 75 pupils (1.54%) have an absolute birth order of five or larger. Most

16-17-year olds in this data set come from a family with two or three other siblings and are often the first- or second-born in their family.

Table 2. Relation between family size and position in birth order

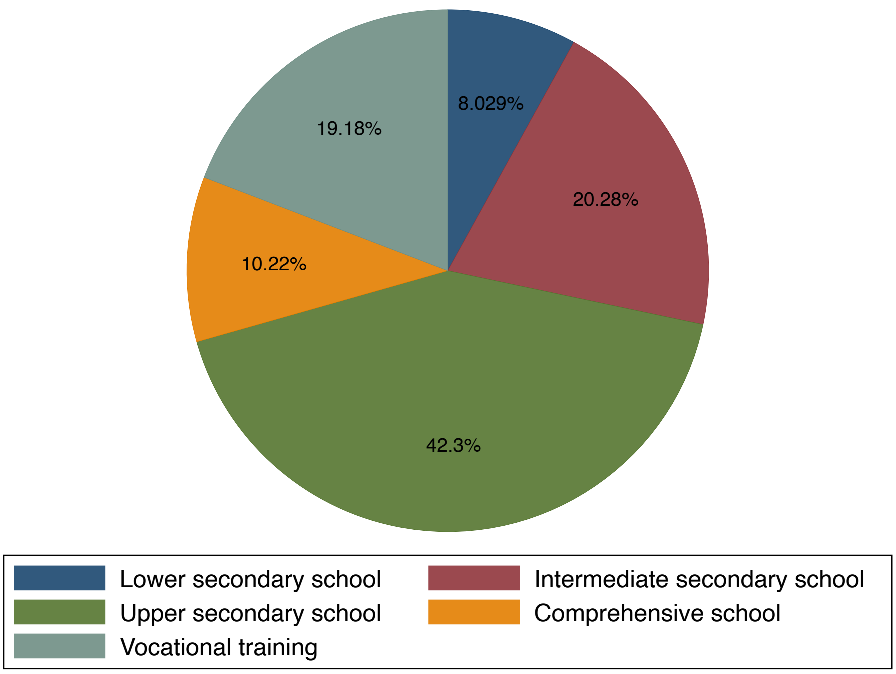
Family Size	Position in birth order									
	1	2	3	4	5	6	7	8	10	Total
1	517	0	0	0	0	0	0	0	0	517
2	973	843	0	0	0	0	0	0	0	1816
3	662	494	332	0	0	0	0	0	0	1488
4	205	193	137	93	0	0	0	0	0	628
5	70	64	46	28	28	0	0	0	0	236
6	26	24	17	16	11	7	0	0	0	101
7	4	5	7	7	7	4	4	0	0	38
8	3	5	3	1	2	1	1	0	0	16
9	1	0	0	0	0	0	0	0	0	1
10	2	2	0	0	0	0	0	0	1	5
11	1	0	0	0	0	0	0	0	0	1
12	0	0	0	2	2	3	2	2	0	11
Total	2464	1630	542	147	50	15	7	2	1	4858

3.2.Institutional details about the German schooling system

In Germany, the schooling system and the number of years of schooling varies slightly depending on the German state the child attends school. Nevertheless, overall, children start primary school at the age of six and it is mandatory to attend school for at least nine or ten years up until the age of fifteen/sixteen. The first four years of schooling are in primary school (grades 1-4). Hereafter, it is decided at which level the pupils will continue their education in secondary school. Lower secondary school (*Hauptschule)* covers the schooling years from grades 5 to 9 and teaches general education, often leading to a vocational qualification. Intermediary secondary school (*Realschule)* offers more extensive education and covers grades 5 to 10 in most states. When completing either lower- or intermediary secondary school, pupils can enrol in vocational training (*Berufsschule/Fachoberschule)*, where an apprenticeship in combination with extra education provides pupils with the necessary skills and knowledge to work in a particular trade or field of work. Next to lower- and intermediary secondary schooling, upper secondary school *(Gymnasium)* is the schooling level which provides the most intensive and academic education. It covers grades 5 to 12 or 13 depending on the German state. Some states also allow students to choose between completing 12 or 13 years. Pupils completing upper secondary school tend to continue their education into tertiary education at university. In addition, comprehensive schools *(Gesamtschule)* are schools which combine all the three different educational levels ("German education system", n.d.). Table A.2. in the Appendix displays the German schooling system in a more detailed overview.

Within this data set, most of the 16-17-year olds are enrolled in upper secondary education, as displayed in Figure 1. Moreover, there are about the same number of pupils enrolled in intermediary secondary education as well as in vocational training. Only about 8% of the 16-17-year olds are enrolled in lower secondary schooling. Figures 2 and 3 relate family size and the position of absolute birth order to the different levels of schooling attended by the 16-17-year olds, respectively. Both the absolute position of birth order as well as family size seem to decrease when the level of school increases from lower- to upper secondary education. This would confirm the expectation of the child quantity-quality trade-off model; with a larger family size or higher position in birth order, child quality is expected to decrease, thus an initial lower level of education is expected. Next to the three initial secondary school levels, 16-17-years olds doing vocational training seem to come from larger families and have a higher position in birth order than those pupils attending upper secondary education. Although, the various school levels and relationships to family size and birth order are explained in this section, the conducted empirical analyses in this paper only considers the typical secondary school levels including lower-, intermediary-, and higher-secondary schooling.

Figure 1. Different levels of schooling attended



Note: The total number of observations for this graph is 5069 16-17-year olds

Figure 2. Relating family size to the level of schooling attended

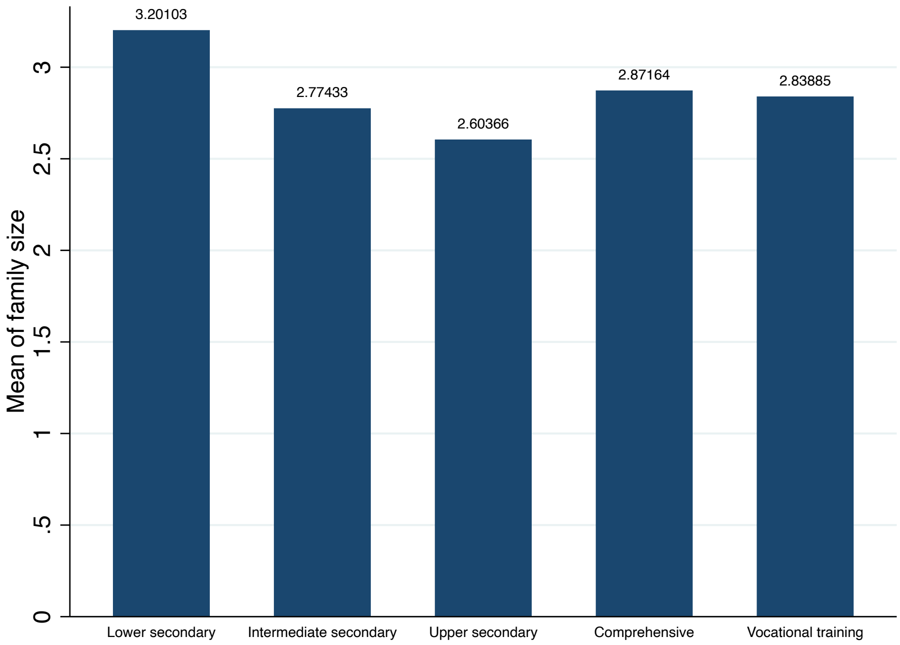
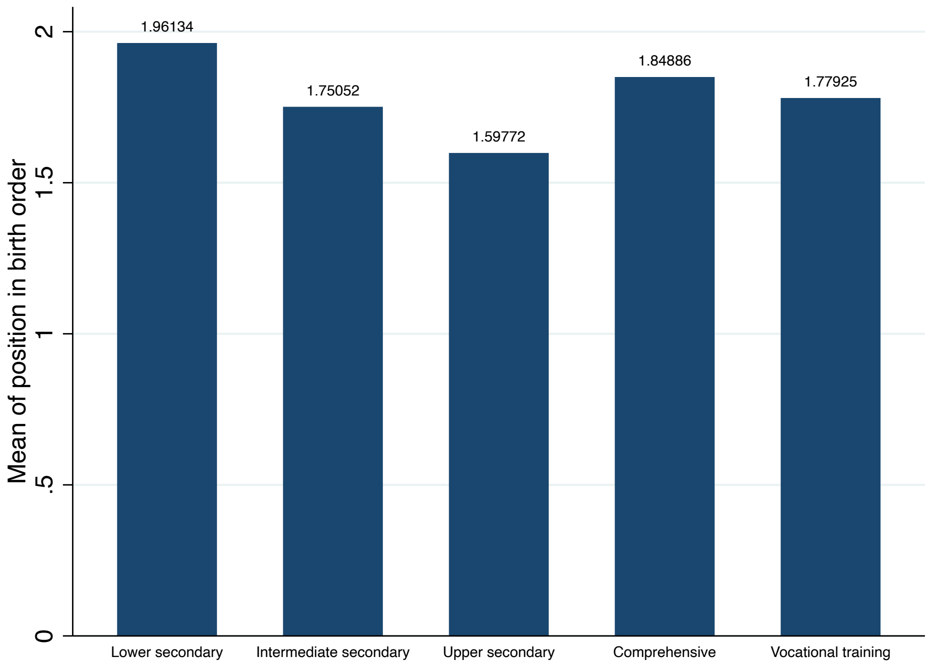


Figure 3. Relating the position in birth order to the level of schooling attended



3.3. The German grading system

The German grading system is captured by a scale of 1 to 6, with one being the best grade and six the worst. Grades larger than 4 are insufficient, thus, the test is failed. In the SOEP-Core data set, pupils' test scores for mathematics, German, and a foreign language are included. The foreign language mostly refers to taking English classes. Previously, Table 1 depicted that, on average, pupils seem to have average test scores in German, mathematics, and a foreign language between 2.8 and 3.

Figures 4 and 5 illustrate the relation of family size and birth order to the test outcomes in German, mathematics, and a foreign language, accordingly. Since the test scores in the German system range from 1 to 6, with a score of 1 being the largest grade possible and 6 being the lowest grade possible, a positive relation is expected to capture the effect of family size/birth order and the obtained test scores. Based on Figure 4, the said expected relationship is not directly visible for either of the grades in German, mathematics or a foreign language. Although, the test grades for either one of the courses seem to increase slightly up until a family size of seven, for families with more than seven children, the test grades fluctuate significantly. Especially since the number of observations of families with more than seven children is relatively scarce, the mean value of test scores is based on less observations. Hence, there might be some outliers that would affect the actual test scores. Moreover, when taking into account the position in birth order, Figure 5 presents similar results. Whilst there seems to be an increasing trend for mathematics when the position in birth order increases, this is not directly visible for either the test grade in German or a foreign language.

Figure 4. Relating family size to the obtained test scores

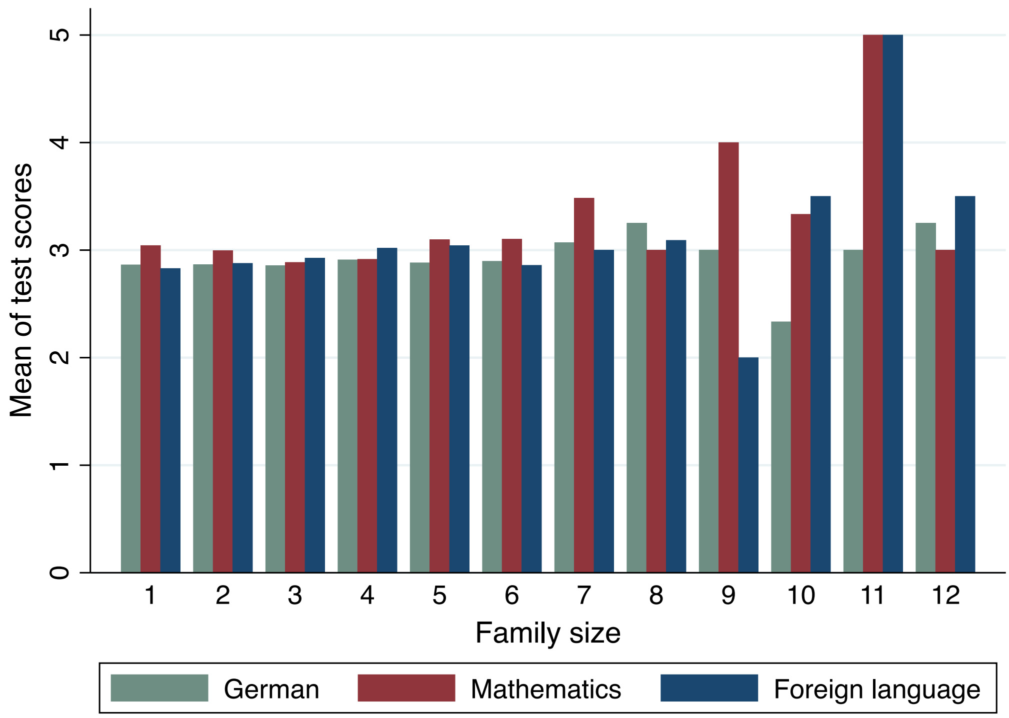
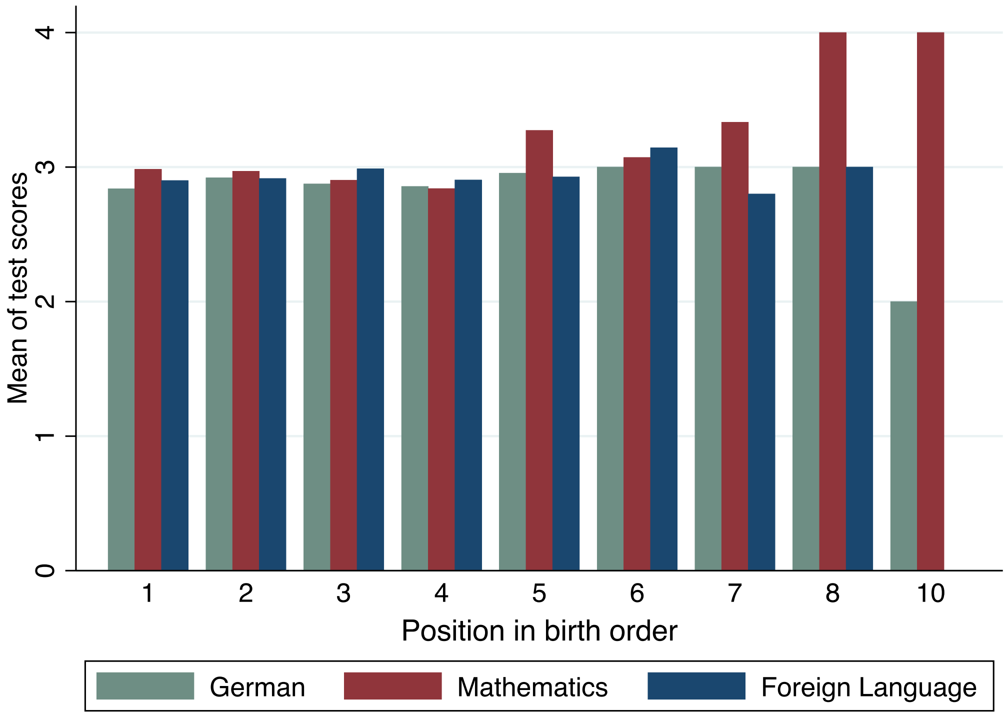


Figure 5. Relating the position in birth order to the obtained test score



4. Empirical methodology

To analyse the exact relation between family size and birth order to educational outcomes in terms of school levels and test results, regressions based on both ordinary least squares (OLS) and two-stage least squares (2SLS) with instrumental variables (IV) are estimated. This section first presents the structure of the regular OLS model. Hereafter, the instrumental variable approach based on twin births and the sex composition of the first two children is outlined in more detail. Finally, this section describes the two different dependent variables implemented and the hypotheses.

4.1. Ordinary Least Squares

An initial OLS equation is regressed as depicted in Equation 1. Equation 1 shows $'i'$ for every 16-17-year-old pupil living in state $'j'$ in year $'t'$ included in this data set. The dependent variable $Educ_{ijt}$ stands for the pupil's educational outcomes which is either measured as the attended school level including lower-, intermediate-, and upper secondary school or the test scores in mathematics, German, and a foreign language. This dependent variable differs from previous research, where typically only educational attainment is investigated as an indicator of "child quality". The main independent variables consist of both $FamilySize_{ijt}$, the number of children in the household, and $RelativeBO_{ijt}$, a generated regressor for the relative position in birth order.

$$(1)\quad Educ_{ijt} = \beta_0 + \beta_1 FamilySize_{ijt} + \beta_2 RelativeBO_{ijt} + \beta_3 FS_j + \beta_4 BY_i + \beta_5 BM_i + \beta_6 X_{ijt} + \beta_7 \delta_t + e_{ijt}$$

Since a first-born child naturally has a larger probability of ending up with fewer siblings than a child with a relatively larger birth order, an initial positive correlation between family size and birth order is expected. Based on this data set, the initial correlation between family size and the absolute position in birth order is 0.5244. As aforementioned, without explicitly taking into account this strong positive correlation, confounding effects between family size and birth order might arise. However, this correlation can be entirely reduced through the inclusion of a relative birth order, which is a generated regressor completely independent from family size itself. In Equation 1, the variable for the relative birth order ($RelativeBO_{ijt}$) is modelled as; $\frac{R-1}{N-1}$, where R presents the absolute birth order and N the family size. The relative birth order is equal to one for the youngest sibling and zero for the oldest sibling (Baland, Bonjean, Guirkinger, Ziparo, 2016). Moreover, due to the mathematical construction of the relative birth order, one child households are omitted from the empirical analysis. With the inclusion of a variable for the relative birth order instead of a regressor for the absolute birth order, the correlation with family size almost completely disappears (-0.06161). In addition to the full reduction of initial positive correlation between family size and birth order, utilizing a relative birth order grasps an additional benefit compared to the use of birth order dummies. Due to the mathematical definition of the relative birth order, family size is indirectly taken into account. In example, this makes it possible to compare 16-17-year-old pupils' birth order in parallel to their family size. Specifically, the average effect on educational outcomes might differ being a second-born in a relatively large- or small family. For instance, a second-born with five other siblings will have a relative birth order of 0.2 ((2-1)/(6-1)), whereas a second-born with only one other sibling has a relative birth order of 1 ((2-1)/(2-1)). With inclusion of solely birth order dummies, the effect of birth order is generated irrespective of the original family size: a second-born is just the second-born child regardless of their initial family size. Consequently, results might differ when analysing the relation to educational outcomes since there is no information whether a second-born pupil comes for a small- or large family.

Besides the main variables of interests, Equation 1 depicts a variety of individual fixed effects such as federal state (FS_j), birth year (BY_i) and birth month (BM_i). Furthermore, X_{ijt} captures several additional controls: household net income, whether the pupil is born in Germany, pupil's school level, father's and mother's level of education, whether parents cared for their child's education, whether parents help their child with studying, pupil's satisfaction with their grades, whether the pupil repeated a year in school, whether the pupil intends to go to university, school's recommendation level of schooling, status of health, and gender. These additional variables captured by X_{ijt} are included in this empirical analysis to control for pupils' socioeconomic- and parental background and thereby, controlling for the possible impact one of these variables might have in influencing pupil's educational outcomes directly. In addition, δ_t in Equation 1 represents the time fixed effects based on the different survey years to control for any possible time trends. However, no specific school fixed effects are included within the analysis, which might produce noise in the final regression results. Nevertheless, since school systems vary depending on the German state, the inclusion of federal states as a control variable should partly diminish this possible bias.

4.2. Two-stage least squares with instrumental variables

As aforementioned, estimating solely Equation 1 is insufficient to determine a causal relationship between family size and birth order on educational outcomes. Although the confounding effects of family size and birth order are resolved by the inclusion of a relative birth order, family size itself remains endogenous and hence, likely biases the obtained OLS results from Equation 1. Family size is expected to be endogenous since the number of children a couple decides to have is not random but likely part of a contingent plan. Family size presumably depends on some unobservable parental characteristics and economic conditions which simultaneously might determine a child's educational outcome directly: Larger sized families might be inherently different from smaller sized ones. Particularly, some omitted variables such as parents' personality traits or -characteristics might be correlated with the error term (e_{ijt} in Equation 1) and simultaneously, directly determine educational outcomes. For instance, parents who earn respectively more money might want less children to focus on their careers. Instantaneously, this larger household budget might directly improve children's educational outcomes regardless of the initial family size. Although including family fixed effects helps to control for this omitted variable bias, family size itself still likely remains endogenous in the regular OLS regressions because of additional concerns with reversed causality. Conditioned on the fact that families have at least one child, parents might decide to have more children depending on the "quality" of their first child. For instance, if the first child performs well in school, parents may be induced to have another child with the expectation that the following child is of "high quality" as well. In this way, larger families might have children of higher quality, and hence, this would bias the true effect that family size has to children's educational outcomes.

To resolve the endogeneity problem of family size due to reversed causality and unobserved omitted variables, an instrumental variable method is implemented. An IV method entails that the endogenous variable family size is determined by a proxy variable (the IV) which provides some exogenous variation. For the IV method to succeed, the IV should satisfy both the relevance condition and exclusion restriction. The relevance condition denotes that the chosen IV should have a causal effect to the variable family size. Moreover, the exclusion restriction infers that the IV should not directly impact the dependent variable educational outcomes but can only affect educational outcomes indirectly through family size. In this empirical analysis, two instrumental variables are exploited to ensure the exogeneity of family size, the aforementioned; (1) *twin birth*s introduced by Rosenzweig and Wolpin (1980) and (2) *the sex-mix of the first two children* described by Angrist and Evans (1998). The following two sub-sections briefly explain the framework of these two IV's.

4.2.1. The occurrence of twin births

Using the occurrence of multiple births as an IV for family size has been very popular among economists (Rosenzweig and Wolpin, 1980; Angrist et al., 2005; Black et al., 2005; De Haan, 2005). Following Rosenzweig and Wolpin (1980), using twin-births to create exogeneity of family size is a valid IV due to satisfying both the relevance condition and exclusion restriction. A twin- or multiple birth namely increases family size directly, hence, satisfying the relevance condition. Moreover, parents' presumably do not intend or expect to conceive a multiple birth. A twin birth can then vary the actual family size from the desired one and therefore, this exogenous variation can be used to estimate the effect of family size on educational outcomes. The general estimation strategy for the twin IV is as follows:

$$(2) \quad Educ_{ijt} = \theta_0 + \theta_1 FamilySize_{ijt} + \theta_2 RelativeBO_{ijt} + \theta_3 FS_j + \theta_4 BY_i + \theta_5 BM_i + \theta_6 X_{ijt} + \theta_7 \delta_t + \varepsilon_{ijt}$$

$$(3) \quad FamilySize_{ijt} = \propto_0 + \propto_1 Twins_{ij} + \propto_2 RelativeBO_{ijt} + \propto_3 FS_j + \propto_4 BY_i + \propto_5 BM_i + \propto_6 X_{ijt} + \propto_7 \delta_t + \eta_{ijt}$$

Equation 2 represents the second stage of the two-stage least squares (2SLS) regression, whereas Equation 3 is the first stage. Similarly to Equation 1, $Educ_{ijt}$ refers to the educational outcomes, $FamilySize_{ijt}$ is a measure for the total number of children in a household, and $RelativeBO_{ijt}$ denotes the measure for relative birth order. Moreover, FS_j, BY_i, BM_i, X_{ijt}, and δ_t depict the same control variables as previously described.

Following De Haan (2005), the variable $Twins_{ij}$ in Equation 3 is a binary variable indicating when the last birth within a family is a twin. For the empirical analysis, the full sample is restricted to only those households up to four children. Therefore, in this case, $Twins_{ij}$ is equal to one when a household has three children and the second birth is a twin, and when a household has four children and the third birth is a twin. In this way, due to the last birth being a twin, the actual family size is expected to deviate from the desired one. According to De Haan (2005), using twins at last birth as an IV for family size holds an additional benefit compared to the structure of $Twins_{ij}$ following Black et al. (2005), where twins at second, third, or higher birth rates are used. For instance, a family with four children who had twins at second birth might also have had four children when the second-born child would have been a singleton. Twins at last birth therefore provides to be a stopping rule, when in contrast a family who had twins at second birth and have four children, might have wanted more children, nonetheless. If a family would have wanted more children regardless of the occurrence of twins at second birth, this would not lead to a deviation from the actual- to desired family size. Hence, by considering only those twins at last birth in a family, this problem is avoided, and exogenous variation can be exploited. Furthermore, this sample restriction, to only include households with maximum four children, allows to control for the possibility that the deviation from desired family size due to the occurrence of a twin birth is likely to matter more for smaller families than for families with already multiple children.

Nevertheless, by restricting the sample to improve identification, part of the interpretation of the estimates is lost. Whilst the sample restriction increases the ability of the instrumental variable model to infer correct predictions, hence improving its accuracy, the actual interpretability of the results decreases. Thus, models which have not considered this sample restriction to increase its interpretability, might lack the necessary accuracy. This paper chooses to improve its identification at the expense of interpretability. By restricting the sample to households up to four children, the first stage of the 2SLS becomes stronger and hence, improves the accuracy of the regressed model.

4.2.2. Sex composition of the first two children

In addition to using twin births as an IV, the sex-mix of the first two children can be used as an IV for family size as well (Angrist and Evans, 1998; Angrist et al., 2005; De Haan, 2005). According to Angrist and Evans (1998), assuming that parents prefer a mixed sibling-sex composition, having two boys or two girls would increase the probability of parents wanting one more child, thereby directly increasing family size and thus, satisfying the relevance condition. Furthermore, since gender is exogenously determined, the sex-mix of the first two children satisfies the exclusion restriction.

Besides solely employing the twins IV, Black et al. (2005) exploit the sex-composition of the first two children as IV as well. Although, the first-stage results indicate the presence of a strong IV, the estimated coefficients of the second-stage regressions imply that an increase in family size significantly improves childrens' educational attainment. Black et al. (2005) do not deem the magnitude of these estimates credible and believe that families with multiple children of the same sex might influence educational outcomes positively and separate from its effect through family size. If this would proof to be true, the sex-mix of the first two children would not provide exogenous variation. However, research has not yet reached a consensus about the effect of siblings' sex-mix to educational outcomes. For instance, while Butcher and Case (1994) do find evidence that a siblings' sex composition affects women's choices regarding education and earnings, Hauser and Kuo (1998) do not offer such support. In addition, neither Kaestner's (1997) results suggest that siblings' sex-mix directly influences individual's educational outcomes. Hence, this paper still takes into account the sex composition of the first two children as an IV for family size since evidence regarding the relationship between siblings' sex composition and educational outcomes yet remains unclear. The general estimation strategy for the sex composition IV is as follows:

$$(4)\quad Educ_{ijt} = \gamma_0 + \gamma_1 FamilySize_{ijt} + \gamma_2 RelativeBO_{ijt} + \gamma_3 FS_j + \gamma_4 BY_i + \gamma_5 BM_i + \gamma_6 X_{ijt} + \gamma_7 \delta_t + \upsilon_{ijt}$$

$$(5)\quad FamilySize_{ijt} = \lambda_0 + \lambda_1 SC_{ij} + \lambda_2 RelativeBO_{ijt} + \lambda_3 FS_j + \lambda_4 BY_i + \lambda_5 BM_i + \lambda_6 X_{ijt} + \lambda_7 \delta_t + \nu_{ijt}$$

Equation 4 represents the second stage of the 2SLS regression, whereas Equation 5 is the first stage. Following Angrist and Evans (1998), SC_{ij} (sex composition) is a binary variable which takes on the value one when the 16-17-year-old is the third-born in the household and his two older siblings, the first- and second-born, have the same sex: either both boys or girls. In contrast, when the third-born pupil has two older siblings who are a boy and a girl, SC_{ij} is equal to zero. Therefore, for this part of the empirical analysis, the sample is restricted to solely those households with two or three children. By doing so, it can be identified to which extent the gender of the first two children matters for the decision of parents wanting a third child. Moreover, presumably, the sex-mix of the first two children will matter less for those households who initially have a wish for a large family size. When a family has five children and the first two are both boys, it is unlikely that this will influence parents' decision of wanting a sixth child. Therefore, by restricting the sample to only households with two or three children, it can be determined to which extent the sex composition of the first two children truly matters. However, similarly as previously explained with the twins IV, due to this sample selection a trade-off arises between identification and interpretation, where accuracy of the model is favoured over the interpretability of the results.

4.3. School levels, test scores, and their hypotheses

This paper employs two different dependent variables to capture pupils' educational outcomes, namely school levels and test scores. For each level of schooling, a binary variable is generated, where the variable is equal to one when a certain level of schooling is attended whereas the binary variable is equal to zero when that specific school level is not attended. Hence, if said level of schooling is not attended, the individual attends one of the other levels of schooling. For the main empirical analysis, only the standard secondary school levels are taken into account: lower-, intermediate-, and upper secondary schooling. Since the three levels of schooling are all binary variables, the simple OLS turns into a linear probability model, where the coefficients can be interpreted as the chances of belonging to said secondary schooling level due to the impact of a one unit change in the regressors. Since the dependent variable is binary, a logit or probit model could have been estimated as well. However, this paper chooses to employ OLS due to its convenience of interpretation. In addition to school levels, more specifically, this paper utilizes the obtained test scores in mathematics, German, and a foreign language as an additional response variable. The grades are converted into standardized tests scores to enable a comparison of results to other studies who also employ test scores as a dependent variable. Separate regressions are run for test scores based on German, mathematics, and a foreign language.

A summary of the main coefficients of interests and their respective hypotheses for the two different dependent variables is offered in Table 3. The coefficients β_1 / β_2, θ_1 / θ_2, and γ_1 / γ_2 refer to the regressions based on OLS and 2SLS using instrumental variables based on twins and the sex-mix of the first two children, accordingly (Equations 1, 2, and 4). Since the type of regression model does not alter the hypotheses of the coefficients belonging to family size and relative birth order based on the theoretical child quantity-quality model and the role of birth order, the same hypotheses are observed for each regression model per response variable.

Table 3. Hypotheses based on school levels and test scores

	(1) Secondary school levels			**(2) Test scores**
	Lower	Intermediary	Higher	
Family size	$Ho: \beta_1, \theta_1, \gamma_1 > 0$	$Ho: \beta_1, \theta_1, \gamma_1 \geq 0$	$Ho: \beta_1, \theta_1, \gamma_1 < 0$	$Ho: \beta_1, \theta_1, \gamma_1 > 0$
Relative Birth order	$Ho: \beta_2, \theta_2, \gamma_2 > 0$	$Ho: \beta_2, \theta_2, \gamma_2 \geq 0$	$Ho: \beta_2, \theta_2, \gamma_2 < 0$	$Ho: \beta_2, \theta_2, \gamma_2 > 0$

The coefficients β_1, θ_1, and γ_1 in Table 3 capture the effect of family size to educational outcomes. The child quantity-quality trade-off model predicts that having relatively more siblings will result in worse individual educational outcomes. Hence, it is expected that children from a larger family will more often attend lower- and intermediary secondary schooling, will less frequently attend higher secondary schooling, and will obtain, on average, worse test scores compared to children who have less siblings. Consequently, β_1, θ_1, and γ_1 are expected to be positive for lower secondary schooling, positive or equal to zero for intermediary secondary schooling, and negative for higher secondary schooling. The effect of family size to intermediary secondary schooling is anticipated to not be as negative or as positive as the effect to lower- and higher secondary schooling, respectively. Hence, its coefficients are expected to be zero or positive. In addition, since the tests scores in this data set indicate a score of 1 being the largest grade possible and 6 being the lowest grade possible, a positive coefficient is expected to capture the relation between family and the obtained test scores in German, mathematics and a foreign language.

Accordingly, β_2, θ_2, and γ_2 grasp the difference in educational outcomes between the first- and last-born within the same family. Because of additional time constrains and the likelihood of resource depletion, children with a larger birth order are expected to have worse schooling performances. Thus, similarly to the expected effect of family size to educational outcomes, β_2, θ_2, and γ_2 are anticipated to be positive for lower secondary schooling, positive or equal to zero for intermediary secondary schooling, negative for higher secondary schooling, and positive for the obtained test scores in German, mathematics, and a foreign language.

5. Regression results based on school levels and tests scores

The following section describes the results obtained from the implementation of OLS- and 2SLS regressions as described in Sections 4.1 and 4.2, respectively. First, the regression results for the different school levels are assessed. Subsequently, the results for the test scores in German, mathematics, and a foreign language are examined. In the end, the obtained outcomes are put into perspective and limitations of this empirical analyses are discussed.

5.1. School levels

Tables 4, 5, and 6 present the regression results using the binary variable for lower-, intermediary, and upper-secondary schooling, respectively. Columns (1) depict the simple OLS regression results without the inclusion of any control variables. Columns (2) portray the simple OLS results with inclusion of the aforementioned control variables captured by FS_j, BY_i, BM_i, X_{ijt} and δ_t. The control variable for the level of schooling is excluded since, in this part, it is employed as the response variable. In Columns (3) to Columns (5), the sample is restricted to those households who only have two, three or four children to enable the implementation of the twins IV. Columns (3) then depict the regular OLS with inclusion of the sample restriction. Columns (4) illustrate the first-stage regression, while Columns (5) demonstrate the second-stage regression results using twins to provide exogenous variation for family size. Correspondingly, in Columns (6) to (8) the sample is restricted to households with solely two or three children to exploit the IV for sex-mix of the first two children. Columns (6) depicts the simple OLS with inclusion of the sample restriction. Columns (7) illustrate the first-stage regression whereas Columns (8) present the second-stage regression results using the sex composition IV.

Overall, across all three schooling levels included in this analysis, both the twins IV and sex composition IV are found to be strong instruments for family size. The coefficients, capturing the relation of said IV's to family size, both significantly and positively impact family size as displayed in Columns (4) and (7) of Tables 4, 5, and 6. Moreover, both IV's have F-statistics larger than ten in the first-stage regressions. Hence, the null hypothesis of the weak identification test, which states that the correlation with the endogenous variable (family size) is close to zero, can be rejected. Therefore, twins at last birth and sex-mix of the first two children are found to be strong instruments to provide exogenous variation for family size. The next three subsections present the regression results specifically for each level of schooling.

5.1.1. Lower secondary schooling

Table 4 displays the regression results using lower secondary schooling as a response variable. As stated by the hypotheses in Table 3 in Section 4.3., a positive coefficient is expected to capture the relationship between family size and relative birth order to the chances of attending lower secondary education. For almost all specifications, the expected direction of the coefficient belonging to family size and relative position in birth order is verified. Only for the second stage using twins IV in Column (5) the found coefficient for family size is negative.

Solely looking at family size, with using a simple OLS without any controls as depicted by Column (1), 16-17-year-olds' chances of attending lower secondary schooling rise by 2.26 percentage points for every extra sibling within the same household. This effect is relatively small yet established to be significant at a 1% significance level. However, with including controls to correct for demographic, time, individual- and parental characteristics, this effect reduces to a small 0.84 percentage points. Although the effect of family size is strongly decreased, it is still significant at a 5% significance level. Nonetheless, as aforementioned, the OLS results are likely to be biased and with inclusion of the instrumental variables, the original significant effect of family size completely disappears as illustrated by the insignificant coefficients in Column (5) and (8). Consequently, due to the inclusion of instrumental variables to correct for the endogeneity of family size, any family size effect to the chances of attending lower secondary schooling seems to disappear.

Similar results are found for the relative position in birth order. Only in Column (1) where initially no controls are included, results are significant: The chances for a last-born of attending lower secondary education rise by 2.04 percentage points, compared to being the first-born within the same household. Nevertheless, this result is likely to be biased due to the endogeneity of family size. Though the coefficients across the different specifications are always positive, with the inclusion of controls and instrumental variables no significant impact of birth order is found to influence the chances of attending lower secondary education.

Table 4. Regression results lower secondary schooling

	(1) Whole sample OLS without controls	(2) Whole sample OLS with controls	(3) OLS restricted by twins IV	(4) First stage twins IV	(5) Second stage twins IV	(6) OLS restricted by sex-mix IV	(7) First stage sex-mix IV	(8) Second stage sex-mix IV
Family Size	0.0226***	0.00837**	0.00889		-0.0882	0.00785		0.0374
	(0.00338)	(0.00354)	(0.00581)		(0.0837)	(0.00887)		(0.0284)
Relative birth order	0.0204**	0.0115	0.0109	-0.104***	0.00102	0.00926	-0.185***	0.0116
	(0.00962)	(0.00942)	(0.00937)	(0.0280)	(0.0128)	(0.00950)	(0.0203)	(0.00963)
Female		-0.00874	-0.00775	-0.0349	-0.0110	-0.00976	-0.00194	-0.00946
		(0.00820)	(0.00833)	(0.0249)	(0.00901)	(0.00875)	(0.0178)	(0.00865)
IV for the presence of twins at last birth				0.507***				
				(0.123)				
IV for the sex-mix of the first 2 children							0.679***	
							(0.0398)	
Constant	0.00589	0.241***	0.244***	2.646***	0.501**	0.211***	2.590***	0.136
	(0.0119)	(0.0753)	(0.0781)	(0.229)	(0.235)	(0.0814)	(0.159)	(0.106)
Observations	4341	3707	3379	3379	3379	2848	2848	2848
R-squared	0.0108	0.210	0.208	0.0769	0.141	0.209	0.162	0.205
Adjusted R-squared	0.0104	0.194	0.190	0.0557	0.122	0.187	0.139	0.184
F-statistic				16.962			291.991	
Controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses. The dependent variable used is a binary variable for attending lower secondary schooling: "1" indicates lower secondary schooling is attended while "0" represents the other types of schooling (intermediary/higher). Columns 3, 4 and 5 include households with two, three, and four children, whereas columns 6, 7, and 8 include households with only two and three children. Controls include fixed effects for survey year, federal state, birth year and birth month. Additional controls are household net income, whether the pupil is born in Germany, father's and mother's level of education, whether parents cared for their child's education, whether parents help their child with studying, pupil's satisfaction with their grades, whether the pupil repeated a year in school, whether the pupil intends to go to university, school's recommendation level of schooling, status of health, and gender.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5.1.2. Intermediary secondary schooling

Table 5 presents the regression results using intermediary secondary schooling as the dependent variable. Following the hypotheses illustrated in Table 3, the coefficients, capturing the relationship between family size and relative birth order to the chances of attending intermediary secondary education are expected to be equal to- or larger than zero. Similarly to the results in Table 4, the expected direction of the coefficients for family size and relative birth order is verified for all regressions but the second stage using twins at last birth as instrument in Column (5). Here, the found coefficient for family size is negative yet insignificant.

As displayed in Table 5, for all specifications, the coefficients belonging to family size and relative birth order are all insignificant, rather small, and close to zero with using OLS or 2SLS. Although, for instance, 16-17-year-olds' chances of attending intermediary secondary schooling rise by a relatively large 6.38 percentage points for every extra sibling within the same household using the sex-mix IV in Column (8), this result is insignificant. Consequently, based on the regression results, the chances of attending intermediary secondary schooling are likely not to be affected by either family size or the relative position in birth order.

Table 5. Regression results intermediary secondary schooling

	(1) Whole sample OLS without controls	(2) Whole sample OLS with controls	(3) OLS restricted by twins IV	(4) First stage twins IV	(5) Second stage twins IV	(6) OLS restricted by sex-mix IV	(7) First stage sex-mix IV	(8) Second stage sex-mix IV
Family Size	0.00499	0.00505	0.00635		-0.0882	-0.00643		0.0638
	(0.00491)	(0.00524)	(0.00883)		(0.0837)	(0.0139)		(0.0445)
Relative birth order	0.0155	0.0149	0.0145	-0.104***	0.00102	0.00602	-0.185***	0.0116
	(0.0140)	(0.0140)	(0.0143)	(0.0280)	(0.0128)	(0.0148)	(0.0203)	(0.0151)
Female		-0.0281**	-0.0278**	-0.0349	-0.0110	-0.0300**	-0.00194	-0.0293**
		(0.0121)	(0.0127)	(0.0249)	(0.00901)	(0.0137)	(0.0178)	(0.0136)
IV for the presence of twins at last birth				0.507***				
				(0.123)				
IV for the sex-mix of the first 2 children							0.679***	
							(0.0398)	
Constant	0.173***	0.0404	0.0770	2.646***	0.501**	0.0424	2.590***	-0.136
	(0.0172)	(0.112)	(0.119)	(0.229)	(0.235)	(0.127)	(0.159)	(0.165)
Observations	4341	3707	3379	3379	3379	2848	2848	2848
R-squared	0.000492	0.199	0.205	0.0769	0.141	0.217	0.162	0.210
Adjusted R-squared	0.0000309	0.182	0.187	0.0557	0.122	0.195	0.139	0.188
F-statistic				16.962			291.991	
Controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses. The dependent variable used is a binary variable for attending intermediary secondary schooling: "1" indicates intermediary secondary schooling is attended while "0" represents the other types of schooling (lower/higher). Columns 3, 4 and 5 include households with two, three, and four children, whereas columns 6, 7, and 8 include households with only two and three children. The controls included are the same as described under Table 4.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5.1.3. Higher secondary schooling

Table 6 demonstrates the regression results using higher secondary schooling as a response variable. A negative coefficient is expected to capture the relationship between family size and relative birth order to the chances of attending higher secondary education as displayed previously in Table 3. Across all regression specifications, the expected direction of the coefficients belonging to family size and relative position in birth order is confirmed. Remarkably, the size of coefficients, capturing the relation of family size and relative birth order to the chances of attending higher secondary education are larger than the magnitude of coefficients in Table 4 which considered lower secondary education as a dependent variable.

For instance, studying the simple OLS regression in Column (1) of Table 6, 16-17-year-olds' chances of attending higher secondary schooling fall by 5.26 percentage points for every extra sibling within the same household. This result is significant at a 1% significance level and initially stronger than the results found for lower secondary schooling in the simple OLS specification in Table 4. With including control variables and the sample restriction to only households with two, three, and four children, a smaller but significant effect of 1.61 and 2.09 percentage points, respectively, is still established in Columns (2) and (3). At first, these significant results would perhaps indicate that compared to other levels of schooling, family size matters more for the chances of a pupil in attending higher secondary schooling. Nevertheless, with controlling for the endogeneity problem of family size by inclusion of instrumental variables, the coefficients become insignificant in Columns (5) and (8), indicating that family size is unlikely to influence the chances of attending higher secondary education.

Perhaps more surprisingly, compared to family size, the effect of relative birth order seems to persist across the different regression models. Starting with OLS in Column (1), the chances of attending higher secondary education for a last-born fall by 6.2 percentage points, compared to being the first-born within the same household. Although, across specifications the size of this effect decreases, the significance of this negative effect is not fully eliminated. Even with employing the said instruments, the effect of relative birth order remains significant at a 5%- and 10% significance level, respectively. Using the twins at last birth IV would indicate that the chances of attending higher secondary schooling for a last-born, compared to first-born, fall by roughly 4 percentage points (Column (5)), whereas using the sex-mix composition IV the chances fall by a smaller but significantly 2.48 percentage points (Column (8)). Thus, compared to the previous findings of lower- and intermediary secondary schooling, the last-born seems to have relatively lower chances of attending higher secondary schooling compared to the first-born within the same household. Although the result is relatively small, birth order seems to matter somewhat for pupils' chances of attending higher secondary schooling.

Table 6. Regression results higher secondary schooling

	(1) Whole sample OLS without controls	(2) Whole sample OLS with controls	(3) OLS restricted by twins IV	(4) First stage twins IV	(5) Second stage twins IV	(6) OLS restricted by sex-mix IV	(7) First stage sex-mix IV	(8) Second stage sex-mix IV
Family Size	-0.0526***	-0.0161***	-0.0209**		-0.0433	-0.0156		-0.0363
	(0.00604)	(0.00511)	(0.00869)		(0.120)	(0.0138)		(0.0441)
Relative birth order	-0.0622***	-0.0372***	-0.0377***	-0.104***	-0.0399**	-0.0232	-0.185***	-0.0248*
	(0.0172)	(0.0136)	(0.0140)	(0.0280)	(0.0184)	(0.0148)	(0.0203)	(0.0150)
Female		0.0479***	0.0472***	-0.0349	0.0464***	0.0481***	-0.00194	0.0479***
		(0.0119)	(0.0125)	(0.0249)	(0.0130)	(0.0136)	(0.0178)	(0.0134)
IV for the presence of twins at last birth				0.507***				
				(0.123)				
IV for the sex-mix of the first 2 children							0.679***	
							(0.0398)	
Constant	0.597***	0.322***	0.334***	2.646***	0.393	0.366***	2.590***	0.419**
	(0.0212)	(0.109)	(0.117)	(0.229)	(0.338)	(0.127)	(0.159)	(0.164)
Observations	4341	3707	3379	3379	3379	2848	2848	2848
R-squared	0.0193	0.504	0.506	0.0769	0.505	0.512	0.162	0.511
Adjusted R-squared	0.0188	0.493	0.495	0.0557	0.494	0.498	0.139	0.498
F-statistic				16.962			291.991	
Controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses. The dependent variable used is a binary variable for attending higher secondary schooling: "1" indicates higher secondary schooling is attended while "0" represents the other types of schooling (lower/intermediary). Columns 3, 4 and 5 include households with two, three, and four children, whereas columns 6, 7, and 8 include households with only two and three children. The controls included are the same as described under Table 4.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5.2. Test scores in German, mathematics, and a foreign language

Tables 7, 8, and 9 adopt the identical specification structure of Columns (1) to (8) in the regression results depicted in Tables 4, 5, and 6. However, the regressions now exploit the individual test scores in German, mathematics, and a foreign language as response variable. Furthermore, school levels are included as an additional control variable. Across all three test scores included in this analysis, both the twins at last birth IV and sex composition IV are found to be strong instruments for family size. The coefficients, capturing the relation of said IV's to family size, both significantly and positively impact family size as displayed in Columns (4) and (7) of Tables 7, 8, and 9. Furthermore, both IV's have F-statistics larger than ten in the first-stage regressions. The next three subsections present the regression outcomes separately for the test scores in German, mathematics, and a foreign language. Since family size and birth order are expected to worsen pupil's test scores, the obtained coefficients are anticipated to be positive as previously portrayed in Table 3.

5.2.1. Test scores in German

Table 7 depicts the results using test scores in German as a response variable. Across all specifications, the expected direction of the coefficient belonging to family size and birth order is verified. The simple OLS estimate in Column (1) indicates that 16-17-year olds are expected to increase their German test score by 0.0248 standard deviations for every extra sibling within the same household. Hence, with increasing test scores, educational performances are projected to worsen. Nevertheless, the deterioration of German test scores is relatively small and only significant at a 10% significance level. Furthermore, as aforementioned, the OLS results are likely to be biased and with inclusion of IV's to correct for the endogeneity of family size, this initially small significant effect is completely removed as displayed in Columns (5) and (8). Hence, family size presumably does not impact the obtained German test scores.

However, in contrast to the coefficients of family size, some of the estimates capturing the effect of relative birth order to German test scores are significant at a 10% significance level. Primarily considering the simple OLS without any control variables, the last-born is expected to retrieve a 0.0645 standard deviations worse grade compared to being the first-born within the same household. Even with the use of the sex composition of the first two children as instrument for family size, the effect of birth order remains significant at a 10% significance level and even slightly increases to 0.0713. Nevertheless, this obtained result does not provide sufficient evidence to establish an actual causal relation between the position in birth order and German test scores. The discovered coefficients are still relatively small, only significant at a 10% level, and with exploitation of the twins IV, the negative relation between birth order and German grades completely disappears.

Table 7. Regression results German

	(1) Whole sample OLS without controls	(2) Whole sample OLS with controls	(3) OLS restricted by twins IV	(4) First stage twins IV	(5) Second stage twins IV	(6) OLS restricted by sex-mix IV	(7) First stage sex-mix IV	(8) Second stage sex-mix IV
Family Size	0.0248*	0.00458	0.00844		0.0897	0.0150		0.00459
	(0.0139)	(0.0134)	(0.0228)		(0.333)	(0.0370)		(0.113)
Relative birth order	0.0645*	0.0515	0.0613*	-0.119***	0.0707	0.0721*	-0.191***	0.0713*
	(0.0392)	(0.0359)	(0.0372)	(0.0311)	(0.0532)	(0.0396)	(0.0223)	(0.0398)
Female		-0.357***	-0.375***	-0.00770	-0.375***	-0.387***	0.0110	-0.387***
		(0.0313)	(0.0331)	(0.0277)	(0.0327)	(0.0366)	(0.0197)	(0.0360)
IV for the presence of twins at last birth				0.477***				
				(0.135)				
IV for the sex-mix of the first 2 children							0.691***	
							(0.0429)	
Constant	-0.105**	1.627***	1.695***	2.702***	1.475	1.733***	2.521***	1.759***
	(0.0486)	(0.278)	(0.298)	(0.244)	(0.946)	(0.329)	(0.170)	(0.419)
Observations	3513	3091	2801	2801	2801	2342	2342	2342
R-squared	0.00160	0.309	0.309	0.0850	0.306	0.317	0.174	0.317
Adjusted R-squared	0.00103	0.291	0.289	0.0581	0.285	0.293	0.145	0.293
F-statistic				12.504			259.387	
Controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses. The dependent variable used is the standardized German test scores. Columns 3, 4 and 5 include households with two, three, and four children, whereas columns 6, 7, and 8 include households with only two and three children. Controls include fixed effects for survey year, federal state, birth year and birth month. Additional controls are household net income, whether the pupil is born in Germany, pupil's school level, father's and mother's level of education, whether parents cared for their child's education, whether parents help their child with studying, pupil's satisfaction with their grades, whether the pupil repeated a year in school, whether the pupil intends to go to university, school's recommendation level of schooling, status of health, and gender.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5.2.2. Test scores in mathematics

Table 8 presents the regression results using the grades in mathematics as a dependent variable. Across almost all specifications, the expected direction of the coefficient belonging to family size and birth order is not verified and therefore, the stated hypotheses cannot be confirmed. Solely looking at family size, although the coefficients in Columns (1) and (2) are positive, the estimates itself are both minor and insignificant. Surprisingly, with inclusion of instruments to create exogenous variation in family size, both the twins and sex-mix IV denote negative estimates. Although for the twins instrument this outcome is insignificant in Column (5), the specification using the sex-mix for the first two children is significant at a 1% level. The estimate presented in Column (8) denotes that 16-17-year olds would perform better in a mathematics test by 0.32 standard deviations when there would be one additional sibling in the household. Although the estimated coefficient represents a rather small effect to the test scores, this result is opposite to the expectations derived from the quantity-quality model of having children.

Similar negative results are found for the relation between the relative position in birth order and obtained mathematics grades. Across Columns (1) to (8), the estimates are always negative and consequently opposite to initial expectations. Nevertheless, simultaneously, none of the estimated coefficients are significant, indicating that birth order does presumably not affect pupils' test scores in mathematics.

Table 8. Regression results mathematics

	(1) Whole sample OLS without controls	(2) Whole sample OLS with controls	(3) OLS restricted by twins IV	(4) First stage twins IV	(5) Second stage twins IV	(6) OLS restricted by sex-mix IV	(7) First stage sex-mix IV	(8) Second stage sex-mix IV
Family Size	0.0198	0.0000503	-0.0681***		-0.371	-0.0713*		-0.321***
	(0.0138)	(0.0139)	(0.0235)		(0.350)	(0.0382)		(0.118)
Relative birth order	-0.0173	-0.0452	-0.0560	-0.116***	-0.0902	-0.0432	-0.190***	-0.0631
	(0.0389)	(0.0373)	(0.0382)	(0.0311)	(0.0553)	(0.0409)	(0.0223)	(0.0415)
Female		0.178***	0.178***	-0.00932	0.175***	0.180***	0.00923	0.180***
		(0.0325)	(0.0340)	(0.0277)	(0.0346)	(0.0378)	(0.0197)	(0.0375)
IV for the presence of twins at last birth				0.479***				
				(0.135)				
IV for the sex-mix of the first 2 children							0.689***	
							(0.0428)	
Constant	-0.0653	0.662**	0.937***	2.699***	1.755*	0.928***	2.521***	1.547***
	(0.0482)	(0.289)	(0.306)	(0.244)	(0.992)	(0.340)	(0.170)	(0.436)
Observations	3515	3089	2797	2797	2797	2340	2340	2340
R-squared	0.000667	0.247	0.255	0.0855	0.209	0.261	0.174	0.247
Adjusted R-squared	0.0000979	0.227	0.233	0.0586	0.186	0.234	0.145	0.220

F-statistic				12.650			259.376	
Controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses. The dependent variable used is the standardized mathematics test scores. Columns 3, 4 and 5 include households with two, three, and four children, whereas columns 6, 7, and 8 include households with only two and three children. The controls included are the same as described under Table 7.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5.2.3. Test scores in a foreign language

Table 9 demonstrates the regression results using the test scores in a foreign language as a response variable. Across the various specifications, the general direction of coefficients belonging to family size is in line with said hypotheses, whereas this is not the case for the estimates belonging to the relative birth order. As displayed by the results in Columns (1) to (3), an increase in family size by one child is expected to worsen 16-17-year olds' foreign language grades by 0.03 to 0.047 standard deviations. The coefficients of Columns (1) to (3) are significant at a 1%, 5%, and 10% significance level, respectively. However, with inclusion of instruments based on twins and the sex composition of the first two children, the coefficients capturing the relation of family size to test scores in a foreign language turn insignificant. Consequently, the obtained grade in a foreign language is likely not to be affected by family size.

Regarding the relative position in birth order, the retrieved coefficients across Columns (1) to (5) are negative, relatively small, and insignificant. Although, Columns (6) and (8) do portray the expected relation between birth order and test scores in a foreign language, the results are negligible. Thus, no significant relation seems to exist between the position in birth order and foreign language test scores either.

Table 9. Regression results foreign language

	(1) Whole sample OLS without controls	(2) Whole sample OLS with controls	(3) OLS restricted by twins IV	(4) First stage twins IV	(5) Second stage twins IV	(6) OLS restricted by sex-mix IV	(7) First stage sex-mix IV	(8) Second stage sex-mix IV
Family Size	0.0467***	0.0295**	0.0399*		-0.148	0.0587		0.0569
	(0.0139)	(0.0140)	(0.0237)		(0.352)	(0.0383)		(0.117)
Relative birth order	-0.0143	-0.0305	-0.0142	-0.117***	-0.0357	0.00420	-0.192***	0.00405
	(0.0390)	(0.0374)	(0.0386)	(0.0312)	(0.0556)	(0.0409)	(0.0224)	(0.0412)
Female		-0.187***	-0.180***	-0.00934	-0.182***	-0.185***	0.00946	-0.185***
		(0.0327)	(0.0344)	(0.0279)	(0.0344)	(0.0379)	(0.0198)	(0.0373)
IV for the presence of twins at last birth				0.480***				
				(0.137)				
IV for the sex-mix of the first 2 children							0.693***	
							(0.0432)	
Constant	-0.123**	1.001***	0.823***	2.681***	1.326	0.762**	2.510***	0.766*
	(0.0487)	(0.290)	(0.310)	(0.246)	(0.991)	(0.340)	(0.171)	(0.431)
Observations	3474	3059	2772	2772	2772	2318	2318	2318
R-squared	0.00331	0.238	0.240	0.0850	0.223	0.243	0.174	0.243
Adjusted R-squared	0.00274	0.218	0.218	0.0578	0.200	0.216	0.145	0.216
F-statistic				12.201			257.204	
Controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses. The dependent variable used is the standardized foreign language test scores. Columns 3, 4 and 5 include households with two, three, and four children, whereas columns 6, 7, and 8 include households with only two and three children. The controls included are the same as described under Table 7.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5.2.4. Comparison of results across school subjects

While the obtained regression results for languages including German and a foreign language are mostly insignificant, some significant negative coefficients are retrieved when exploiting mathematics as a response variable to family size. These results could possibly be explained by characteristic differences between said subjects. While learning languages requires verbal ability in terms of reading, writing, and speaking, mathematics is based on a specific set of rules which are improbable to change over time. Mathematics, therefore, would possibly increase the opportunity to study together with fellow pupils or siblings compared to learning languages. If pupils have relatively more brothers and sisters, siblings can help each other study mathematics since the said subject is based on common- and more abstract rules. Although, siblings can also assist each other with learning languages, especially with verbal practise, reading, writing, and the learning of new words is a more individual task. Hence, these suggestions could explain why mathematics test scores is likely to be influenced by family size while language grades overall seem to remain unaffected. Nevertheless, future research would have to examine whether such a distinguishment between the role of family size and various school subjects such as languages and mathematics can truly be established.

5.3. Discussion of the results: The alignment between theory and empirics

Although both the child quantity-quality framework and the role of birth order to child welfare are theoretically well-established, the empirical findings in this paper do, in general, not align with the suggested hypotheses. The insignificance of these results might be explained by substantial socioeconomic changes in developed countries over the last years. While the child quality-quantity framework may have been empirically accurate 60 years ago when Becker (1960) initiated his theory, since then, the role of fertility and institutions in developed countries has altered considerably. For instance, nowadays, in developed countries, fertility rates are lower than ever following the demographic transition and in most industrialized countries, primary- and secondary schooling is typically freely accessible and often requires very little contribution of parents in terms of money (Doepke, 2015). Furthermore, it is generally mandatory for children to attend school for at least a certain number of years. This is likely to limit the differences between children who, 60 years ago, were likely to drop out of school to, in example, help out in the household. Moreover, nowadays, more women tend to work full-time or part-time, therefore, increasing the household budget available to be spend on their children. Hence, the initial lower fertility rates, frequently well-functioning schooling systems, and the increase of female participation in the labour force might all contribute to relax the initial assumption of a strict budget constraint which is implied to cause the trade-off between the quantity and quality of children. Therefore, within the context of developed countries, family size might not directly impact children's educational outcomes as much as it might have done in the past when household budget constraints were much more stringent. This could explain why nowadays little empirical validation for the quantity-quality framework is found using data from industrialized countries and controlling for the endogeneity of family size.

Nevertheless, the assessment of the quantity-quality trade-off model might provide the expected significant results in developing countries where family budget constraints are likely to be more pressing. Developing countries are often in the earlier stages of the demographic transition, and although their overall fertility rates might be falling, family sizes are, on average, much larger compared to the ones in developed countries. Furthermore, for children in developing countries there is often less provision of accessible high-quality schooling and the opportunity costs of this education are much larger. For instance, some children from the household tend to help out with family work and child labour is often still common, thus, increasing the likelihood of parents pulling out their children from school at a relatively young age (Bharadwaj, Lakdwala, and Li, 2020). Consequently, the higher opportunity costs of education and less public provision of high-quality education could possibly strengthen the effect of the quantity-quality trade-off in shaping fertility choices and educational outcomes in developing countries (Doepke, 2015). Indeed, Baez (2008) employs Colombian data and suggests that a significant quantity-quality trade-off is visible: Children from larger families in Colombia accumulate, on average, about one year less of schooling, are twice more likely to be obstructed in schooling and, are less likely to attend education in general. Consequently, the empirical analysis of the role of family size to child outcomes might be more pressing in developing countries where the assumption of a fixed budget constraint seems to persist.

Besides the role of family size, the obtained results in this paper capturing the relation between relative birth order and children's educational outcomes mostly seem to be negligible as well. The assumption of a strict parents' time constraint and possible depletion of resources, which initially causes this trade-off between first- and last-borns within the same household, might, similarly, nowadays not be as persistent as 60 years ago and therefore, cause the overall insignificant results. Due to overall lower fertility rates and the high-quality provision of education in the developed world, later-born children still retrieve the same high-quality education as their older siblings even if parents would have less time to spend with the later-born child. Furthermore, because of the possible relaxation of a fixed budget constraint as aforementioned, it seems doubtful that households in developed countries would fully deplete all their resources. Hence, the likely intra-household differences between first- and last-borns might not be as prevalent nowadays.

However, in developing countries intra-household resource allocation might be more unequal and therefore, would amplify a significant birth order effect. Within the context of developing countries, different historical inheritance systems, lineage practises, and patterns of child-preferences often exist where, depending on birth order and/or gender, some children are favoured over others. For instance, with a primogeniture rule, the first-born child inherits all families' assets. This structure would give rise towards discrimination against all the other younger siblings and possibly lead to increased differences between children based on birth order and educational outcomes as well. Indeed, Esposito, Kumar, and Villaseñor (2020) verify the negative relation of birth order to educational outcomes using Mexican census data. They establish that in Mexico, a first-born male has a stronger educational advantage over its other siblings, especially if the younger siblings are female. Consequently, in developing countries such gender specific preferences and lineage structures are likely to strengthen the intra-household trade-off between siblings and their individual welfare, while in the developed world such preferences often are not or less present.

5.4. Limitations of this paper

This paper has several empirical limitations that have to be taken into account which might cause noise to the regression estimates and could explain the occasionally unanticipated results. First, comparing the obtained coefficients from OLS- and 2SLS regressions cannot be examined without caveat. While OLS specifications estimate the average treatment effect (ATE), the average treatment of a randomly selected individual from the population, 2SLS regressions evaluate the local average treatment effect (LATE), the ATE for an instrument-specific subpopulation. The LATE interpretation considers only those observations for who the instrument used changes the family size decision. Hence, the causal effect of family size is only considered for this specific subgroup and, therefore, the OLS- and 2SLS results cannot be interpreted without caution since the two methodologies apply to different populations (Pischke, 2016). Although, the usefulness of LATE to test the hypotheses in this paper might be limited because of analysing a "treatment effect on the treated" (Pischke, 2016, p.13) and thus, not its full population, the results still provide information about the relation between family size, birth order, and educational outcomes which might be relevant for future policy implications.

Second, this paper does not control for the potential effect of birth spacing. Families with five children whose birth spacing is relatively little might differ considerably in their relationship between birth order and educational outcomes compared to families with five children whose birth spacing is comparatively larger. Without taking this possible influence into account, the outcomes for the relative position in birth order might be confounded with the effect of birth spacing. Black et al. (2005) exploit the possibility that birth spacing might influence educational outcomes directly. Nevertheless, by adding separate control variables to account for the differences in birth spacing, their overall estimation results remain unchanged. Yet, including birth spacing as further control variables creates an additional problem. The obtained results then should be interpreted with caution since parents might optimally plan birth spacing which creates additional endogeneity in the empirical analyses.

Third, this paper does not control for within household sibling spill-over effects either. Both Qureshi (2017) and Nicoletti and Rabe (2019) have established that a significantly positive spill-over effect from the oldest to the youngest child exists in terms of schooling outcomes and educational attainment. If the older siblings are to help the younger ones, then there might actually be benefits to being the last-born within the same household. Nevertheless, controlling for such sibling-spillover effects is empirically very challenging due to unobserved common characteristics between siblings and problems of reverse causality. Hence, this paper has not taken this effect into account.

Fourth, there might be economies of scale within larger families which this paper has not controlled for. If larger families conceive multiple children of the same gender, clothing for instance can be re-used and therefore, less money will need to be spend which would increase the household budget available. This suggestion is in line with the initial doubt by Black et al. (2005) in using the sex-composition for the first two children as instrument for family size.

Last, the test scores in German, mathematics, and a foreign language this paper employs as response variables are not part of a generalized national schooling test. Therefore, this might cause noise besides the lack of controlling for school fixed effects and consequently, influence the obtained results.

6. Conclusion

This paper aimed to investigate a potential causal relationship between family size and birth order to pupil’s educational outcomes in terms of school levels and test scores in Germany. By utilizing an instrumental variable approach based on twins at last birth and the sex-mix of the first two children, exogenous variation in family size was provided. Moreover, by generating a variable for the relative position in birth order, the confounding effects between birth order and family size were eliminated. Hence, by employing this empirical strategy, results could be interpreted causally.

Although a negative relation between family size and birth order to educational outcomes was expected, overall, no such effect for either family size or birth order on educational outcomes were established by this study. Although initially most of the OLS regressions did illustrate a significant negative relation, these significant results disappeared and mostly converged to zero when instrumental variables to control for the endogeneity of family size were included. This indicates that the OLS results are biased and that other factors besides family size and birth order presumably determine a "child's quality" in Germany. However, comparing the results between OLS and 2SLS still have to be interpreted with caution because of the different interpretations based on ATE and LATE, respectively. Nevertheless, results do indicate that an increase in family size seems to improve mathematics test scores by 0.32 standard deviations. Furthermore, the relative position in birth seems to matter somewhat for a 16-17-years olds' chances of attending higher secondary schooling, where a significant, although relatively small, negative estimate of 2.5- to 4 percentage points was found across the specifications. Hence, in general, no real empirical evidence for the child quantity-quality trade-off or impact of position in birth order was established and consequently, the hypotheses of this paper were rejected. A caveat is that this paper has several empirical limitations, such as the use of test scores as dependent variables and the lack of additional control variables for birth spacing, sibling spill-over effect, and households' economies of scale, that might influence the obtained results.

This study does not directly establish meaningful policy implications; it did not discover any real impact of family size or birth order to educational outcomes in Germany. Furthermore, the significant results that were found for both birth order and family size had a relatively small magnitude. According to the outcomes of this paper, children, nowadays, do not necessarily perform better in secondary schooling if their family had been smaller or if they would have been the first-born within their family. Consequently, there is limited opportunity for policy makers to promote "child quality" based on, for instance, fertility limiting programs.

For future research, more research should be devoted to studying how between-families differences and within-families variations might shape pupil's educational performances in both developed- and developing countries. For the developed world, besides using educational data, future research must study if any long-term socioeconomic effects due to family size and birth order exist. Although, some studies have already focused on this by employing data about labour market participation and teenage birth as dependent variables (Black et al., 2005), no consensus about this has been established in the literature to date. Furthermore, research must expand its knowledge by utilizing data from various developed countries to establish whether there is indeed no such child quantity-quality trade-off or role of birth order to educational- or other socioeconomic outcomes. If indeed a consensus is to be reached that no such relations exists, economists would have to rethink the "production function" that determines child outcomes. Such research could shape the future for the economic analysis of fertility in developed countries. Besides focussing solely on the developed world, additional research must focus on studying the relation between family size, birth order, and child welfare employing data from developing countries as well. Although data collection might be more challenging, it is paramount to establish whether family size and birth order do shape children's educational outcomes in developing countries where fertility rates are larger, opportunity costs of attending education are higher, and high-quality public schooling is scarcer. In conclusion, although this paper did not establish a causal impact of family size and birth order to 16-17-year olds' educational outcomes in Germany, studying its relations remain of great importance. By carefully analysing the quantity-quality trade-off model and role of birth order in both developed- and developing countries, research has the potential to shape the understanding of the determinants of child welfare, the demographic transition, and eventually economic development.

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List of Figures and Tables

Figures

Tables

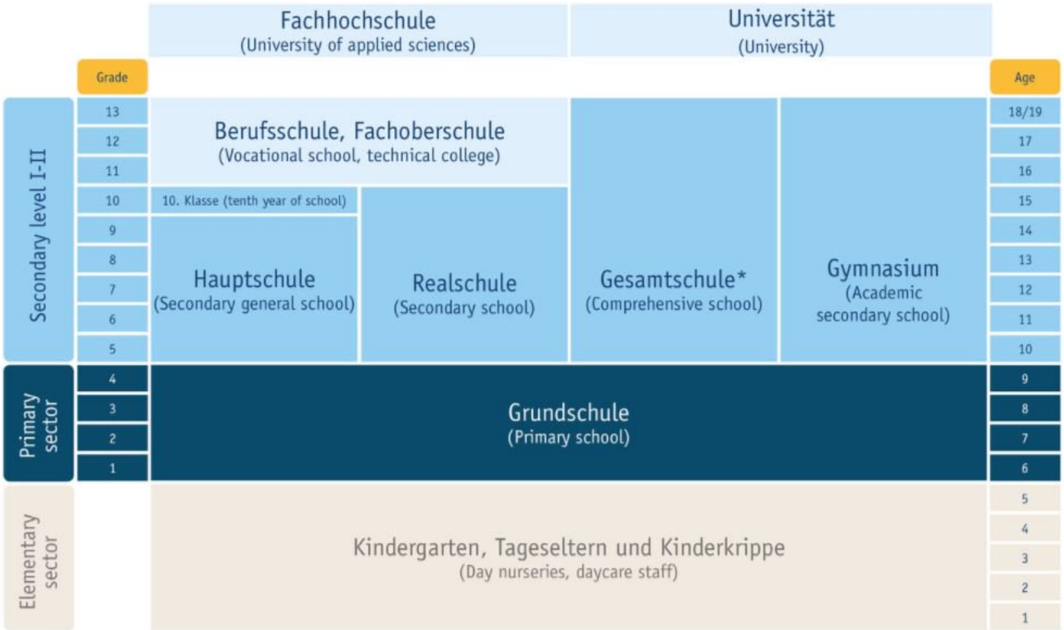
Appendix 1: Supplementary material

Table A.1. Overview of the literature discussed

Study	Country	Time	Method	Outcome variable	Findings (+/0/-)
Blake (1981)	United States	Multiple studies used from: 1955, 1960, 1970, 1972–1980	OLS with control variables for parents' socioeconomic status	Educational attainment	(-) Family size (0) Position in birth order
Hanushek (1992)	United states	1971-1975	OLS with control variables for family socioeconomic status and teachers' characteristics	Test scores	(-) Family Size (+) Position in birth order
Behrman and Taubman (1986)	United States	1977, 1981, 1982	OLS with control variables for parental background and family-size	Educational attainment and earnings	(-) Position in birth order with schooling (0) Position in birth order with earnings
Härkönen (2014)	West-Germany	1981–1983, 1989, 1998–1999	Fixed effects models	Educational attainment	(-) Position in birth order
Eschelbach (2013)	West-Germany	1946–1977	Family fixed effects model	Attendance of secondary schooling: categorical variable	(-) Position in birth order
Rosenzweig and Wolpin (1980)	India	1969–1971	2SLS; Occurrence of twin-births as IV	Age-standardized schooling index	(-) Family size
Angrist and Evans (1998)	United States	1970, 1980, 1990	2SLS; Sex composition of the first two children as IV	Female labour supply	(-) Family size
Black, Devereux, and Salvanes (2005)	Norway	1986–2000	2SLS; Occurrence of twin-births as IV with birth order dummies	Educational attainment (additionally: earnings, employment, and age of childbearing)	(0) Family size (-) Position in birth order
Mogstad and Wiswall (2016)	Norway	1986–2000	Unrestricted models allowing for non-linearity with 2SLS using twin birth as IV	Educational attainment	(-) Family size (-) Position in birth order
De Haan (2005)	The Netherlands and United States	United States: 1957, 1964, 1975, 1992 The Netherlands: 1952, 1983, 1993	2SLS; twins at last birth and sex composition of the first two children as IV	Years of education	(0) Family size (-) Position in birth order
Angrist, Lavy, and Schlosser (2005)	Israel	1983 and 1995	2SLS; occurrence of twin births and sex composition of the first two children as IV	Educational attainment, fertility rates, and earnings	(0) Family size
Baez (2008)	Colombia	2000 and 2005	2SLS; sex composition of the first two children as IV	School performances: school attainment, attending school, being held back in school	(-) Family size

				(additionally: household resources, attachment to the labor market, health care, domestic violence)	
Esposito, Kumar, and Villaseñor (2020)	Mexico	2010	Logit model with relative birth order and control variables for household characteristics	On-track grade enrolment	(-) Position in birth order

Table A.2. Germany's educational system



* Offers different degrees depending upon the agreements in the individual federal states: e.g. certificate of secondary general school, secondary school, academic secondary school.
Retrieved from: IW Köln. https://www.deutschland.de/en/topic/knowledge/overview-of-the-german-school-system

Appendix 2: Declaration of Originality MSc Thesis

By signing this statement, I hereby acknowledge the submitted MSc Thesis titled

“The effect of birth order and family size on educational outcomes in Germany: An empirical assessment of the quantity-quality trade-off of children”

to be produced independently by me, without external help.

Wherever I paraphrase or cite literally, a reference to the original source (journal, book, report, internet, etc.) is provided.

By signing this statement, I explicitly declare that I am aware of the fraud sanctions as stated in the Education and Examination Regulations (EERs) of SBE, Maastricht University.

Place: Susteren, the Netherlands

Date: May 30, 2021

First and last name: Evie Graus

Study programme: MSc Economics, Double Degree Track

ID number: i6131776

Signature: